

Could Gamma Rays Sterilize Earth?

ASTRONOMY[®]

Witness Hale-Bopp's Grand Finale

April 1997 U.S. \$3.95

U.K. £2.25

Can. \$5.25

ICD 08070

Meet Our Galaxy's New Planets



- Playing Cosmology's Wild Card
- Russian Scopes are Coming



LX50

Advanced technology at the most affordable prices ever.

■ **Battery-Powered, Completely Cordless Operation!** Meade LX50 models operate for more than 50 hours from six AA-size batteries inserted through the telescope's control panel. Or use the standard-equipment 25 ft. cord to power the telescope directly from any auto cigarette lighter plug.

■ **Standard-Equipment Declination Motor and Hand Controller:** Plug the hand controller into the LX50 control panel and you're ready for full dual-axis drive capability at any of 4 photo-guide or microsllew speeds: 2x, 8x, 16x, or 32x, plus quartz-controlled sidereal-rate tracking in R.A. Switch speeds instantly using the speed-control button on the hand controller. Dual-axis drive rate is indicated by a red LED.

■ **Multi-Function Control Panel:** Includes connectors for CCD autoguider; for the standard-equipment Declination motor; and for the optional Magellan II Computer-Corrector (below). A North-South switch permits telescope operation anywhere in the world.

■ **Super Multi-Coated Optics:** The exact same EMC super multi-coated optical tube assemblies included with Meade LX200 models.

■ **Massive LX200-type Fork Mounts:** Meade LX50 mounts are manufactured of the same

virgin aluminum castings as Meade LX200 Schmidt-Cassegrains. Massive, rigid mountings that include the Meade LX worm-gear drive system with low periodic error for advanced photographic or CCD imaging applications. *No competing mid-priced equatorial mountings even come close.*

SPECIFICATIONS: 7", 8", and 10" LX50's—Each complete telescope includes 8" or 10" f/10 Schmidt-Cassegrain or 7" f/15 Maksutov-Cassegrain optical tube assembly with EMC super multi-coatings; heavy-duty LX200-type fork mount; 5.75" LX worm gear system in R.A.; multi-function control panel; DC servo Declination motor; manual and electric slow-motion controls on both axes; setting circles on both axes; keypad hand controller; 4-speed drive controls on both axes; battery compartment accepting six (user-supplied) AA-size batteries; 25 ft. power cord for telescope operation from 12v. auto cigarette lighter plug; 6 x 30mm (7" and 8" models) or 8 x 50mm (10") viewfinder; 1.25" diagonal prism; MA25mm multi-coated eyepiece (1.25"); standard equatorial wedge with elevation scale, bubble level, and azimuth control; complete operating instructions.

8" LX50 Schmidt-Cassegrain	\$1395.
10" LX50 Schmidt-Cassegrain	1695.
7" LX50 Maksutov-Cassegrain	1795.
Variable-Height Field Tripod	295.
7" Maksutov-Cassegrain Tube Ass'y	1295.

Packing and shipping in the 48 states: 8"—\$105; 10"—\$145; 7"—\$125; 7" Tube Assembly—\$65.



Meade Magellan™ II Computer-Corrector for LX50 Telescopes: Plug the Magellan II into the control panel of your LX50 and enjoy an incredible range of advanced capabilities. ■ Fast manual slewing to any object, either from input RA and Dec or from the 12,218-object database. ■ High-resolution 4096-pulse encoders (5.3 arc-minute precision), concealed in special LX50 encoder compartments. ■ Large 32-character, red-backlighted display. ■ Quick 2-star alignment. ■ Four-speed (2x, 8x, 16x, 32x sidereal) dual-axis drive corrector/microslewing system.

#2024: Magellan II for LX50's—Includes Magellan II hand controller (right); encoders for both axes; all required mounting hardware. Installs to any LX50 in minutes. \$495. + \$15 packing and shipping in the 48 states.



only
\$495!



LX50 models shown with optional Field Tripod.



The largest-selling
serious telescopes
in the world.

LX200

In virtually every country in the world where serious telescopes are sold, more Meade LX200's are sold than all competing models combined. Consider these standard-equipment specifications:

■ **Superb Optics:** LX200 diffraction-limited imaging capabilities are a legend in the industry; we regularly receive reports stating that optical performance approaches that of a fine ED apochromatic lens.

■ **Automatic GO TO Capability:** Meade LX200's are the only commercial telescopes ever manufactured that automatically GO TO any input R.A. and Dec., or to any of 64,359 objects in the onboard database, to a precision of one arc-minute or better.

■ **Meade LX200 High-Precision Pointing™** is so precise it permits the positioning of every selected object on every commercially-available CCD chip every time, automatically — a feat that no other telescope priced under \$40,000 can accomplish.

■ **Permanently-Programmable Smart Drive™** routinely achieves 5 arc. sec. periodic error, an observatory standard.

■ **9-Speed Dual-Axis Electronics:** Electronics that cover every possible contingency of telescope positioning—from 2x photo-guide, to 32x image centering, to 8°/sec. slewing across the sky, as well as 6 other dual-axis drive speeds in between.

■ **Field Operation:** No other telescopes of such incredible capabilities transport so readily for field operation. The optional #1812 Electronic DC Adapter (a compact 4 oz. unit) allows for field powering directly from an automobile cigarette lighter plug.

SPECIFICATIONS: 7", 8", 10", and 12" LX200's—Each complete telescope includes 8" or 10" (f/6.3 or f/10) or 12" f/10 Schmidt-Cassegrain or 7" f/15 Maksutov-Cassegrain optical tube assembly with EMC super multi-coatings; heavy-duty fork mount with 4" polar ball bearing, dual-axis 5.75" worm gears, and multi-function control panel; manual and electric slow-motion controls on both axes; keypad hand controller with digital readout display, permanently programmable Smart Drive, 9-speed drive controls on both axes (7-speed on 12"), High-Precision Pointing, and GO TO controller; 64,359-object onboard celestial software library; 25 ft. power cord and adapter for telescope operation from 115v.AC; 8 x 50mm viewfinder; 1.25" diagonal prism (7", 8", 10") or 2" diagonal mirror with 1.25" adapter (12"); Series 4000 Super Plössl 26mm eyepiece; standard field tripod (7", 8", 10") or giant field tripod (12"); operating instructions.

8" LX200 Schmidt-Cassegrain	\$2795.
10" LX200 Schmidt-Cassegrain	3195.
12" LX200 Schmidt-Cassegrain	4495.
7" LX200 Maksutov-Cassegrain	3295.

Packing and shipping in the 48 states:
8"—\$105; 10"—\$145; 12"—\$215;
7"—\$125.



Write, call, or fax Meade Instruments for your free copy of the 94-page Meade 1997 General Catalog.

Prices shown are suggested U.S. mail-order retail prices.



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Tim Puckett

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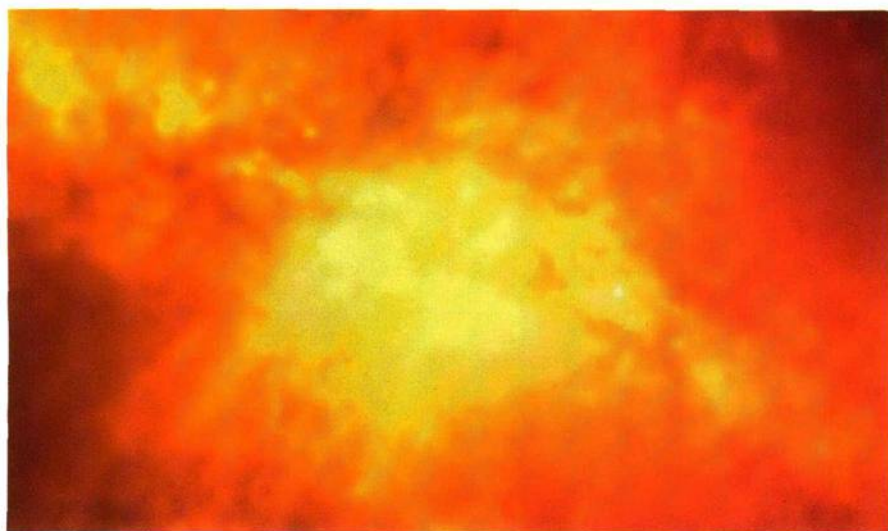
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Keeping Up With the Sky

With this issue, *ASTRONOMY* has an editorial advisory board. You can read about the accomplishments and inclinations of our nine board members — scientists, writers, and an astronaut — on page 20. To know why we wanted them on our side, read on.

For 25 years, *ASTRONOMY* has relied mostly on the efforts of a team of talented, well-educated, and hard-working editors. It's a small, well-oiled machine. However, the universe that is our beat is growing larger and more complex with each day — and especially on days when the Hubble Space Telescope captures a new batch of images. In this decade alone our collection of known galaxies has grown from 10 billion to 100 billion.

Many of the objects and events of the night sky — including the 12 to 20 planets revealed to us this year (see "The Strange New Planetary

Zoo" on page 42) — are way out of reach of backyard telescopes. Many are out of the reach of any scope that depends on visible light.

What we need to know about and explain for you is often as grand and theoretical as any wild human fancy. We have decided to extend our reach. We will now have agents and advisors in the finest research institutions in the world. Our board includes several gifted, eloquent writers who will keep us in mind with their own astronomical ideas and keep us informed of their personal literary discoveries. Already board members have alerted us to wonderful books we will excerpt for you, new writers who we've set to work on stories for the summer issues of *ASTRONOMY*, and sparkling new research. We're excited and inspired by their efforts and we hope you will be too.

One name you won't see gracing our masthead is Carl Sagan's. In November, Sagan agreed to be an official editorial advisor, following years when he had inspired and counseled many of us. In December, he died. We are grieved personally and professionally. On page 38, you will find appreciations of Sagan written by colleagues and friends.



Lynette Cook

Bonnie Bilyeu Gordon

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<http://www.kalmbach.com/astro/astronomy.html>

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MAGELLAN

8" LX10

All the optical performance of
Meade 8" LX50 and LX200 Schmidt
Cassegrains...for only **\$995!**

For the serious amateur astronomer on a more limited budget, or for the more casual observer who nonetheless demands the very finest in optical performance, the Meade 8" LX10 satisfies every requirement. *No other similarly-priced 8" Schmidt-Cassegrain offers such a range of standard features — or such a range of important options for special applications. Standard-equipment includes:*

Super Multi-Coated Optical System: The LX10 includes the exact same 8" Schmidt-Cassegrain optical tube assembly as more expensive Meade 8" LX50 and LX200 models. Super multi-coatings (not available even as an *option* on competing 8" telescopes) are included with every LX10 optical system, for the highest levels of light transmission and image contrast.

Equatorial Fork Mounting: The relatively light weight, but very stable, LX10 fork mounting provides all of the rigidity required for sensitive high-power applications of the telescope, or for photographic or CCD imaging. Ball bearings on the polar axis complement the precise action of the internal worm gear system.

Cordless, DC-Powered Electronic Motor Drive: A drive system that includes an electronically-regulated DC servo motor for automatic *sidereal-rate* tracking. The drive is powered by four AA-size batteries that fit conveniently through the telescope's control panel; battery life is in excess of 50 hours.

Worm-Gear System: The LX10's 5.75"-diameter worm gear produces extremely smooth, regular motion in R.A., with low periodic error — a periodic error that permits such advanced capabilities as long-exposure astrophotography or CCD imaging.

Hand Controller: Essential for micro-guiding the telescope during long-exposure astrophotography, the LX10's pushbutton hand controller enables precise corrections in R.A. at 2x speed. With the optional electric Declination motor added to the telescope, the hand controller is functional at 2x speeds on both telescope axes. Both the standard-equipment hand controller and the optional electric Declination motor plug into the telescope's control panel.

SPECIFICATIONS: 8" Model LX10 — Includes 8" Schmidt-Cassegrain optical tube assembly with EMC super multi-coatings (D = 203mm; F = 2000mm, f/10); fork mount with setting circles, manual slow-motion controls, and locks on both axes; 5.75" LX worm gear reduction system; sidereal-rate electronically-regulated DC servo motor drive; 4-pushbutton hand controller for 2x speed corrections in R.A.; battery compartment accepting four (user-supplied) AA-size batteries (telescope may also be powered from an auto cigarette lighter plug, using optional 25 ft. cord); 6 x 30mm viewfinder; eyepiece-holder and diagonal prism (1.25"); MA25mm multi-coated eyepiece; standard equatorial wedge with elevation scale, fine elevation control, and 360° azimuth orientation capability; complete operating instructions.

\$995. (+ \$65 packing & shipping in the 48 states)

LX10 Field Tripod 195.

LX10 Electric Declination Motor System 85.

#2014 Magellan I Telescope Computer System
for LX10, with 12,218-object database. 375.

The 94-page Meade 1996 General Catalog is available free of charge from Meade Instruments or from authorized Meade dealers. Prices shown are suggested U.S. mail-order prices.

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Add the optional LX10
Declination Motor for dual-
axis corrections at 2x.

Meade 8" LX10
Schmidt-Cassegrain Telescope,
shown with standard-equipment
equatorial wedge and hand controller
and with optional LX10 Field Tripod.

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Meade Pictor 208XT
AUTOGUIDER/IMAGER
 complete **\$495**



Meade Pictor 216XT
AUTOGUIDER/IMAGER
 complete **\$695**



Meade Pictor 416XT
AUTOGUIDER/IMAGER
 complete **\$1695**
 includes \$800 Meade CCD Equipment System



Revolutionary Meade Pictor CCD's are now the world's largest-selling autoguiders and imagers for the amateur astronomer. No other electronic imaging systems offer such an incredible range of capabilities at such amazing price levels. At only \$495 the **Pictor 208XT** produces on the PC display fine, high-resolution 8-bit images *in seconds* of the Moon and planets,

or, in 2 or 3 minutes, of thousands of deep-space objects. At \$695 the **Pictor 216XT** enables advanced 16-bit imaging and is *by far* the finest autoguider/imager ever made available at under-\$1000. At \$1695 the **Pictor 416XT** permits professional-level imaging capability for the amateur astronomer: an electronic camera capable of producing with amateur telescopes

images of the Moon, planets, and deep-space that match or exceed the photographic images obtained with many observatory telescopes. All models are available for immediate shipment. **For complete information on Meade CCD imaging systems write, call, or fax for your free copy of the 94-page Meade 1997 General Catalog.**



Pictor 208XT images (top to bottom): Ring Nebula (M57), 25" reflector, Jack Newton; Galaxy (M81) in Ursa Major, 12" LX200, Scott Roberts; Trifid Nebula (M20), 8" LX200, John Hoot.

Pictor 216XT images: Whirlpool Galaxy (M51), 12" LX200, John Hoot; Globular Cluster (M13), 25" reflector, Jack Newton; Galaxy (M83) in Hydra, 12" LX200, Scott Roberts.

Pictor 416XT images: Crab Nebula (M1), 25" reflector, Jack Newton; Jupiter, 10" LX200 with Stellar Products AO-2 seeing adapter, Dr. Donald Bruns; Moon (crater Plato), 16" f/6 reflector, Dr. Donald Parker.

MEADE ETX

90mm Maksutov-Cassegrain



Meade ETX Astro Telescope. Shown with optional #64 Photo Adapter.

SPECIFICATIONS: ETX Astro Telescope—Includes Maksutov-Cassegrain optical tube assembly (D = 90mm, F = 1250mm, f/13.8) with EMC super multi-coatings; internal flip-mirror system for either straight-through or 90° observing position; equatorial fork mount with slow-motion controls, locks, and setting circles in R.A. and Dec; table tripod with elevation scale on center tripod leg; motor drive system with internal battery compartment accepting three (user-supplied) AA-size batteries; 8 x 21mm achromatic erect-image viewfinder; Series 4000 Super Plössl 26mm eyepiece (1.25"); operating instructions. **Net weight 9 lbs. \$595*** (+ \$20 packing and shipping in the 48 states)

*Suggested U.S. mail-order retail price.

Now you can have
diffraction-limited
imaging and
ultraportability
...at only
\$595,
complete!

The revolutionary Meade ETX goes anywhere with you at a moment's notice and presents the finest optical images ever made available in an ultraportable telescope.

Optical System: Manufactured at the Meade Irvine, California facility, ETX diffraction-limited optics produce images so high in contrast, brightness, and resolution that the ETX consistently outperforms telescopes of much larger apertures. **Equatorial Fork Mount:** Precise polar alignment in *seconds*, just by extending the center tripod leg to read your latitude on the inscribed scale. **Cordless Motor Drive:** The internal drive system operates from 3 AA-size batteries that power the motor drive for more than 50 hours. A North-South switch permits operation anywhere in the world. **Flip-Mirror System:** Flip the internal optical flat mirror "up" for 90° observing; flip the mirror "down" for terrestrial observing with the optional #932 45° Erecting Prism or for photography with the optional #64 Photo Adapter. **Standard accessories** include a Series 4000 Super Plössl 26mm eyepiece and 8 x 21mm erect-image viewfinder.



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MEADE

STARFINDER DOBSONIANS

No other competing Dobsonians include this listing of standard-equipment features:

Primary and Secondary Mirrors of Low-Expansion Pyrex® Glass: Unlike the plate glass optics of other Dobsonians that can become thermally unstable, all Meade Dobsonian optics are made of Grade-A fine-annealed Pyrex glass — the exact same professional-quality optics used on Meade Starfinder Equatorials.

Rigid, Durable, Beautiful Dobsonian Mountings, manufactured of cabinet-quality materials, provide extremely smooth motions of the telescope in both altitude and azimuth. Both telescope axes ride on zero-backlash Teflon/Nylon bearings, facilitating the quick location and easy tracking of celestial objects.

Full-Size 1.25" Rack-and-Pinion Focuser: For smooth, precise focusing of the image without wobble or backlash. Focus travel is 2.6"; accepts 1.25" eyepieces.

4-Vane Steel Secondary Mirror System: Permits locked-in support and precise centration and alignment of the secondary mirror.

Multi-Coated MA25mm Eyepiece (1.25"): The Meade Modified Achromatic 25mm eyepiece yields sharp, high-resolution imaging to the field edge.

5 x 24mm Viewfinder: Included with all Starfinder Dobsonian models for quick object-location in the main telescope. With crosshair eyepiece and 2-ring bracket.

Optical Tubes: Starfinder Dobsonians include the same strong, spiral-wound Sonotube™ optical tubes used on Starfinder Equatorials (right), tubes with excellent insulating characteristics that reduce internal thermal currents to an absolute minimum.

Performance! Meade Starfinder Dobsonians and Equatorials are the largest-selling Newtonian reflectors of their apertures in the world. Every Starfinder model opens up the skies to an extremely wide range of serious visual observing; all 110 Messier objects, thousands of NGC objects — nebulae, galaxies, star clusters, in all their variations of form, color, and extent, as well as the Moon and planets in stunning high-resolution detail. Starfinder Dobsonians are telescopes for visual observing; motor-driven Starfinder Equatorials may be used, in addition, for lunar and planetary photography, and even for limited deep-space photography.

Packing & UPS Shipping Charges to any address in the 48 states: 6"—\$39; 8"—\$49; 10"—\$69; 12.5"—\$79; 16"—\$45 packing, shipped truck freight collect.

Dobsonian Deluxe Accessory Package only \$49.95!



Outfit your Meade Dobsonian with all of the most popular accessories for advanced observing. At the time you order any Dobsonian model, specify the following Deluxe Accessory Package for your telescope, in place of the

standard-equipment focuser, viewfinder, and eyepiece, **for a total of only \$49.95 additional:**

- 1 - Meade #77 2" Giant Rack-and-Pinion Focuser, with machined aluminum eyepiece-holders for both 2" and 1.25" eyepieces; includes drawtube lock and 2.6" focuser travel. (reg. \$59.95)
- 1 - Meade #637 6 x 30mm Achromatic Viewfinder, with wide 7° field; 2-ring metal bracket. (reg. \$49.95)
- 3 - Meade MA9mm, 12mm, and 25mm multi-coated eyepieces, 1.25" barrel — eyepieces for the full range of lunar, planetary, and deep-space observing. (reg. \$37.95 each)

Purchased separately, the Deluxe Accessory Package sells for \$223.75!

Meade Magellan I Telescope Computer System

Attach the optional Magellan I Telescope Computer System to your Starfinder Dobsonian and finding any of 12,218 celestial objects, or any object of known R.A. and Dec., is almost as easy as pointing the telescope! Magellan I's database includes the following objects:

- 7,840 NGC objects; the complete NGC catalog
- 4,093 IC objects from the Index Catalog
- 125 user-defined objects
- 110 Messier objects; the complete catalog
- 42 alignment stars for the Magellan system
- 8 major planets, from Mercury to Pluto
- 12,218 objects, total

Magellan I is supplied complete with control/display unit (4" x 5" x 1.25"); premium-grade, high-resolution encoders for each telescope axis (encoder precision is 5.3 arc minutes); RS-232 serial interface; bracket for placement of the controller on the telescope tube; and attachment hardware. Just add the user-supplied 9v. transistor radio battery, and Magellan I is ready to use. First-time installation is quick and simple.



#2010: for Meade Starfinder Dobsonian
6", 8", 10", 12.5", or 16" \$295.
Packing & shipping in the 48 states—\$15.

STARFINDER DOBSONIAN TELESCOPES Shown with standard-equipment 5 x 24mm viewfinder and 1.25" rack-and-pinion focuser.

All prices plus packing and shipping, as noted above.

6" f/8
\$319

8" f/6
\$419

10" f/4.5 \$599
Shown with optional
Magellan I Telescope
Computer System

12" f/4.8
\$895

16" f/4.5
\$1195



MEADE

STARFINDER EQUATORIALS

DC-powered drive systems for fully automatic tracking, and a wide range of standard-equipment features:

Professional-Grade Optical System: Includes hand-figured, parabolic primary mirror and elliptical flat secondary, both of Grade-A Pyrex glass. Optics are multi-coated and meet the theoretical limits of resolution.

Precision Equatorial Mount: Manufactured of machined aluminum to tolerances of .001" or better, with 4"-dia. pier and die-cast tripod legs for rock-solid support of the optical tube. Moves effortlessly from object to object on precision bearing surfaces. Polar and Dec. shafts are 1" solid steel. Setting circles on both axes.

Battery-Powered Cordless Drive System! Provides fully automatic tracking of celestial objects. Operates for more than 50 hours from 6 (user-supplied) AA-size batteries. Control panel also permits powering the telescope from 12v. auto cigarette lighter plug, using optional 25 ft. cord.

2" Giant Focuser: Meade #77 2" giant rack-and-pinion focuser is included as standard equipment, with eyepiece-holders for both 2" and 1.25" eyepieces.

Accessories and Components: #637 6 x 30mm viewfinder with wide 7° field; multi-coated MA25mm eyepiece (1.25"); strong, durable, spiral-wound optical tube with attractive white finish.

Starfinder Equatorial 16: Includes equatorial mounting with 1.5" steel shafts, Sealmaster ball bearings, 6" dia. pier, and 6 x AA-size battery-powered worm gear drive; 8 x 50mm viewfinder; #77 2" giant focuser.

Packing & UPS Shipping Charges to any address in the 48 states: 6"—\$65; 8"—\$75; 10"—\$90; 16"—\$55 packing, shipped truck freight collect.

Meade Magellan Telescope Computer Systems

Magellan I: Use the Magellan I computer to manually slew the telescope quickly to any of 12,218 database objects, or to any object of known R.A. and Dec. Specifications and object database are identical to Magellan I for Starfinder Dobsonians (see facing page).



- #2011: for Meade (DC-powered) Starfinder Equatorial 6", 8", or 10" \$295.
#2012: for Meade (DC-powered) Starfinder Equatorial 16" 295.

Magellan II Computer-Corrector: Plug the Magellan II into the control panel of your Meade Starfinder Equatorial and you have all the capabilities of the Magellan I, above, including 12,218-object database, plus a 4-speed (2x, 8x, 16x, 32x), dual-axis, drive corrector/microslewing system.



- #2018: for (DC-powered) Starfinder Equatorial 6", 8", 10" .. 495.
#2019: for (DC-powered) Starfinder Equatorial 16" 595.

Packing & shipping in the 48 states: Magellan I—\$15, Magellan II—\$20.

Special Eyepiece Offer! At the time you order any Meade Starfinder Equatorial telescope, you can buy 2 additional multi-coated eyepieces, MA9mm and 12mm, for a total of \$29.95! Purchased separately, the 2 eyepieces sell for \$75.90.



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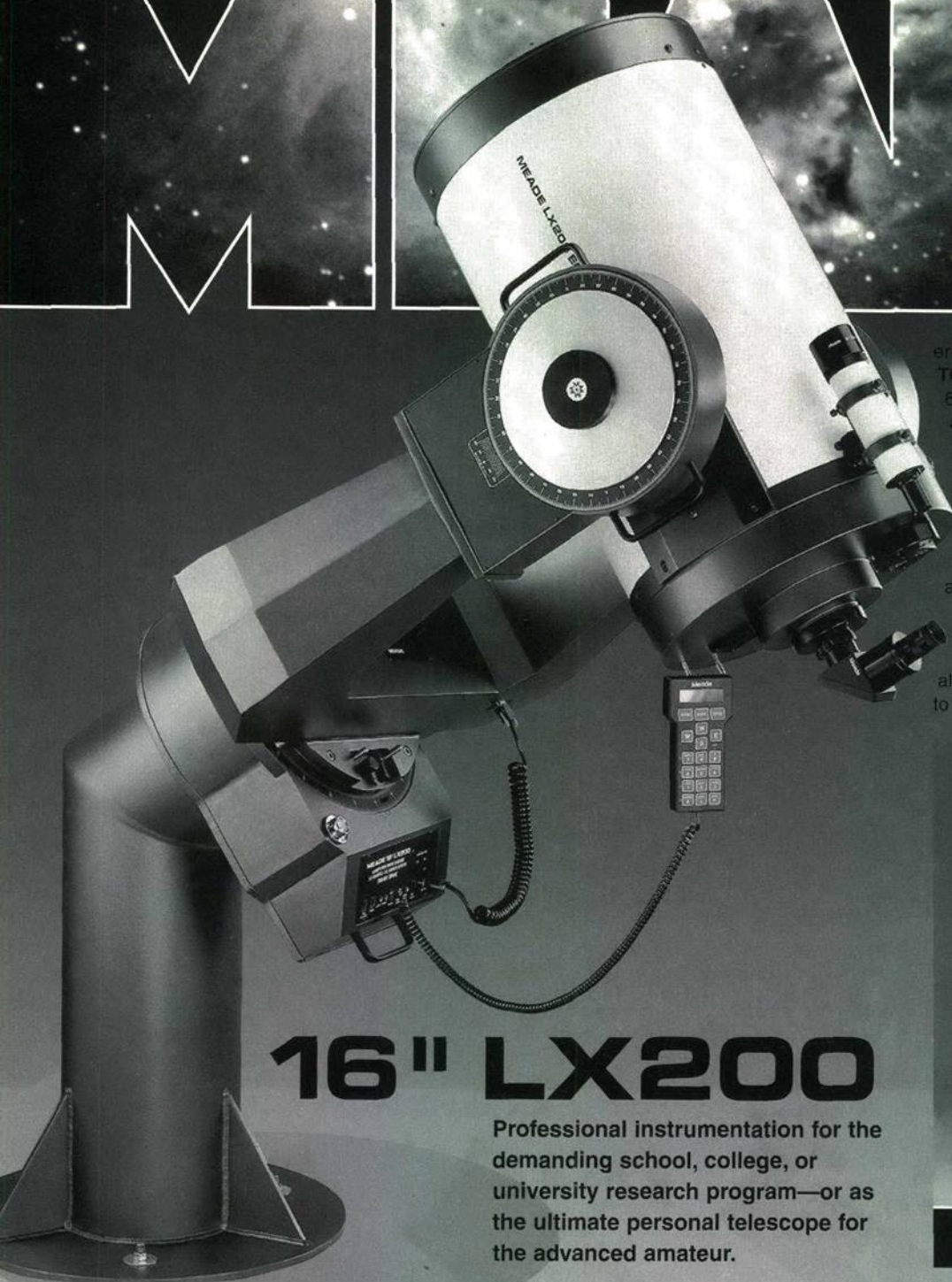
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M M M M D E



16" LX200

Professional instrumentation for the demanding school, college, or university research program—or as the ultimate personal telescope for the advanced amateur.

Professional-grade 16" f/10 Schmidt-Cassegrain optical system meets or exceeds advanced requirements; includes BK7 correcting plate with EMC super multi-coatings for high UV transmission. ■ **Massive one-piece fork mount** permits substantial auxiliary equipment to be piggybacked with rock-solid stability. ■ **Large 11" worm gears** on both axes, with factory-programmed Smart Drive™; periodic

error less than 5 arc seconds. ■ **Automatic GO TO capability** to any object in the onboard 64,359-object database or to any input R.A. and Dec. ■ **High-Precision Pointing™** to within one arc-minute in the GO TO mode. ■ **DC servo drive systems** with integrated encoders and planetary gearboxes; encoder resolution: 0.13 arc secs. ■ **Six pushbutton-controlled drive-speed rates**, from photo-guide to fast-slew on both axes, simultaneously. ■ **Microprocessor controlled sidereal-rate tracking** in AZ or EQ modes with quartz accuracy. ■ **Home-Pulse Acquisition** permitting remote alignment and operation through a modem link to the telescope's RS-232 interface. ■ **Control**



Meade 16" LX200 Schmidt-Cassegrain, with Supergiant Transportable Field Tripod.

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The Meade 16" LX200 is in continuous production at the Meade Irvine, Calif. factory. **Delivery time:** 4 to 12 weeks. **Price:** \$14,950, complete with supergiant field tripod, plus \$385 packing and shipping in the 48 states; prices slightly higher with permanent altazimuth or equatorial pier.



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MEADE

EYEPIECES AND ACCESSORIES

Series 4000™ Super Plössl

52° field; multi-coated



Meade 4-element Super Plössls, updated and redesigned to utilize the latest in optical glass-types, are the finest general-purpose eyepieces available. For observing hairline lunar and planetary detail, splitting close doubles, or for deep-space; guaranteed to deliver more contrast and image sharpness than any other brand. Rubber eyeguards fold down for eyeglass wearers—a feature not available on competing brands. Multi-coated. All focal lengths through 32mm are parfocal.

Super Plössl (SP; 4-elements; 1.25"; 52°):
 6.4, 9.7, 12.4, 15, 20, 26mm each: **\$79.95** (3.45)
 32mm (52°); 40mm (44°) each: **99.95** (3.79)
 56mm (52°; 27°) **199.95** (5.48)

Series 4000™ Ultra Wide Angle

84° field; multi-coated



The ultimate eyepieces; extreme image sharpness over an amazing 84° field. A perfect optical match with Schmidt-Cassegrains and fast Newtonians.
Ultra Wide Angle (UWA; 8-elements; 1.25"; 84°)– 4.7mm: \$169.95 (3.94); **6.7mm: 199.95** (3.94); **8.8mm (1.25"/2"): 239.95** (5.87); **14mm (1.25"/2"): 299.95** (6.28)

Series 4000™ f/6.3 Focal Reducer/Field Flatteners

Manufactured to exclusive Meade optical designs; threads on to any Meade or Celestron Schmidt-Cassegrain rear cell and converts f/10 scopes to f/6.3 (or f/6.3 SCT's to f/4), while significantly flattening the field. Use with SCT visual or photo accessories. Actual visual field is increased by 56%, for fine wide-field views of star fields and nebulae. In astrophotography, reduces exposure times by about 50%, while producing an actual field diameter of 1.5" at the film plane. A tremendous aid with CCD imagers in reducing image size for locating and centering images on CCD chips. 4-element optics; multi-coated; 41mm clear aperture.



\$129.95 (3.60)

2x Telenegative Barlow (1.25")

#122: Doubles eyepiece power with sharp, high-resolution, high-contrast imaging on telescopes of all types. 27mm dia. (26mm clear aperture). Excellent corrections for chromatic and spherical aberrations at all photo-visual wavelengths. Multi-coated. 1.25"



\$47.95 (3.45)

2x Short-Focus Barlow (1.25")

#126: Only 2.5" long, the #126 works well with any telescope accepting 1.25" eyepieces, even those with limited focus range. Maintains the high image quality of the #122, above. Insert the #126 into star diagonal for 2x or insert star diagonal into #126 for 3x. 26mm clear aperture.



\$47.95 (3.45)

2x-3x Variable Barlow (1.25")

#127: Precision internal sliding lens assembly permits continuously variable power settings between 2x and 3x. Engraved scale indicates power in use. Yields bright, sharp, high-contrast images on telescopes of all types. Multi-coated; 1.25"



\$59.95 (3.45)

2" Diagonal Mirror

#929: Permits use of wide-field 2" oculars. Threads on to rear cell of Meade and Celestron SCT's. Includes multi-coated precision optical flat made at the Meade factory; with 1.25" eyepiece adapter. #930: Same as #929 but with 2" barrel to fit into focuser with 2" eyepiece-holders.



#929 or #930, each: **\$99.95** (5.87)

45° Erecting Prisms

Fully coated roof prisms to invert the astronomical image in Schmidt-Cassegrains or refractors during terrestrial observations, while presenting a convenient 45° observing angle. Specify #927 (.965"), #928 (1.25"), or #931 (fits .965" focuser, accepts 1.25" eyepieces).



\$42.95 (3.45)

World's Most Advanced Illuminated Reticle Eyepiece

Series 4000 Plössl 9mm, with rubber eyecup and micrometric X-Y positioning of the reticle within the field. Greatly facilitates locking on the guide star. Sharp high-power imaging, excellent eye relief. Wireless red LED illuminator with adjustable brightness control. Multi-coated optics. Internal batteries included.



Bullseye reticle. 1.25". **\$149.95** (3.45)

Series 4000 Plössl 9mm—Same as above but with 6 ft. cord and plug for Meade LX3, LX5, LX6, LX100, LX200, and APO power panels, in place of wireless illuminator.

\$129.95 (3.45)



Series 4000 Photo-Visual Color Filters (1.25")—Premium filters, made of purest crown optical glass, dyed in the mass. For increased contrast and resolution on the Moon and planets. Thread into the barrels of virtually all 1.25" eyepieces sold today. Fully coated.

#8 Lt. Yellow; #11 Yellow Green; #12 Yellow; #21 Orange; #23A Lt. Red; #25A Red; #38A Dark Blue; #47 Violet; #56 Lt. Green; #58 Green; #80A Blue; #82A Lt. Blue

each **\$14.95** (2.29)
 Set #1–4 filters: #12, #23A, #58, #80A **49.95** (2.98)
 Set #2–4 filters: #11, #25A, #47, #82A **49.95** (2.98)
 Set #3–4 filters: #8, #21, #38A, #56 **49.95** (2.98)

Series 4000 Moon Filter (#ND96): Reduces glare and irradiation during lunar observing. 13% uniform light transmission across the visual spectrum. Threads into 1.25" barrels. **\$16.95** (2.29)

#905 Variable Polarizer (1.25")

For glare reduction in observing the Moon. Includes two Polarizer filters mounted in a machined cell and permits continuously variable light transmission from 5% to 25%, to compensate for varying lunar surface brightness according to the Moon's phase and the aperture of the telescope. Accepts 1.25" eyepieces.



\$49.95 (4.27)

Modified Achromatic Eyepieces

Meade 3-element MA eyepieces yield sharp, well-corrected images on the Moon, planets, and deep-space at a reasonable price. Multi-coated; threaded for filters; 1.25" barrel diameter. Apparent field: 40°. MA 9, 12, 25, 40mm.



each: **\$37.95** (3.45)

MA12mm Illuminated Reticle Eyepiece

Excellent 3-element optical system, long eye relief, fully coated, with double crossline reticle. Wireless red LED illuminator and variable brightness control. 1.25" Batteries included. **\$99.95** (3.45)
 As above but with 6 ft. cord and plug for Meade telescopes with power panels, in place of wireless illuminator. **\$79.95** (3.45)



Camera Adapters

Professional-quality adapters for rigid coupling of telescope-to-camera. Use for either Eyepiece-Projection or Prime Focus. Precision-machined of aluminum and brass, threaded for filters. Use with T-mount, available separately.



.965": **\$27.95**. 1.25": **\$29.95** (2.98)

Variable Tele-Extender

For eyepiece-projection photography with any Meade or Celestron SCT. Threads on to eyepiece-holder. Sliding cell with lock permits wide range of projection magnifications with the same eyepiece. Use with T-mount for your camera.



\$39.95 (2.98)

Variable-Projection Camera Adapter (1.25")

Machined sliding cell allows variable projection power in eyepiece-projection photography; permits precise selection of correct photo power in lunar and planetary photography; threaded for filters. Use with T-mount for your camera.



\$39.95 (2.98)

T-Adapters for SCT's

Rigidly couples camera to telescope for prime focus photography with any Meade or Celestron Schmidt-Cassegrain. Use with T-Mount for your 35mm camera.



\$26.95 (2.98)

Series 4000™ 2x Apochromatic Barlow Lens

#140: The most advanced Barlow lens available for commercial telescopes, the Meade #140 includes 3-element, multi-coated, air-spaced optics. Doubles the power of any eyepiece with which it is used and yields images absolutely unmatched in resolution, contrast and color correction. The #140 optically complements any telescope — refractor, reflector, or Schmidt-Cassegrain. Accepts 1.25" eyepieces. Mechanical components are of machined aluminum and brass. Lens diameter is 28mm; clear aperture 28mm.



\$79.95 (4.27)

Series 4000™ Super Wide Angle

67° field; multi-coated



For exquisite wide-angle images at low-to-medium powers, with pinpoint edge-of-field resolution. Ideal for star fields, galaxies, and other deep-space phenomena. SWA 13.8mm, 18mm, and 24.5mm are superb complements to the #140 Barlow, above.

Super Wide Angle (SWA; 6-elements; 1.25"; 67°)–13.8mm: \$139.95 (3.94); **18mm: 149.95** (3.94); **24.5mm: 179.95** (4.68); **32mm (2"): 239.95** (5.87); **40mm (2"): 299.95** (6.28)

Series 3000™ Plössl

50° field; multi-coated



The very latest in eyepieces from Meade optical designers, new Meade Series 3000 Plössls yield the finest image corrections obtainable from the classical 4-element Plössl design. Available in a wide range of focal lengths from 5mm through 25mm. All five eyepieces are parfocal, so that, at most, only slight refocusing of the image is necessary from eyepiece to eyepiece. Unlike competing moderately-priced Plössls, Meade

Series 3000's are multi-coated for maximum light transmission and image contrast. Chrome-plated brass barrels are threaded for standard filters. Manufactured exclusively for Meade instruments by one of Japan's leading lensmakers, Series 3000 Plössls produce fine, high-resolution results on reflectors, refractors, and Schmidt-Cassegrains of any focal ratio.

Series 3000 Plössls (4-elements; 1.25"; 50°)
 5, 6.7, 9.5, 16, 25mm each: **\$49.95** (3.45)



Series 4000 Nebular Filters—Premium multi-layer interference filters, the finest obtainable. Use broadband ("B") filters to block most forms of light pollution; use narrowband ("N") filters in heavily light-polluted areas or for extremely high-contrast observing of faint nebulae.

#908B—Threads into 1.25" eyepieces, 26mm dia. **79.95** (3.45)
 #910B—Threads into 2" eyepieces, 44mm dia. **119.95** (3.85)
 #911B—Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia. **99.95** (3.94)
 #908N—Threads into 1.25" eyepieces, 26mm dia. **89.95** (3.45)
 #910N—Threads into 2" eyepieces, 44mm dia. **129.95** (3.85)
 #911N—Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia. **119.95** (3.94)

Series 3000™ Plössl 40mm 44°

An excellent complement to the Series 3000 Plössls above, this all-new Plössl 40mm produces spectacular low-power, wide-field results with any telescope. Includes classical 4-element Plössl optics, multi-coated. Barrel dia. 1.25"; threaded for filters. Apparent field: 44°.

\$79.95 (3.79)

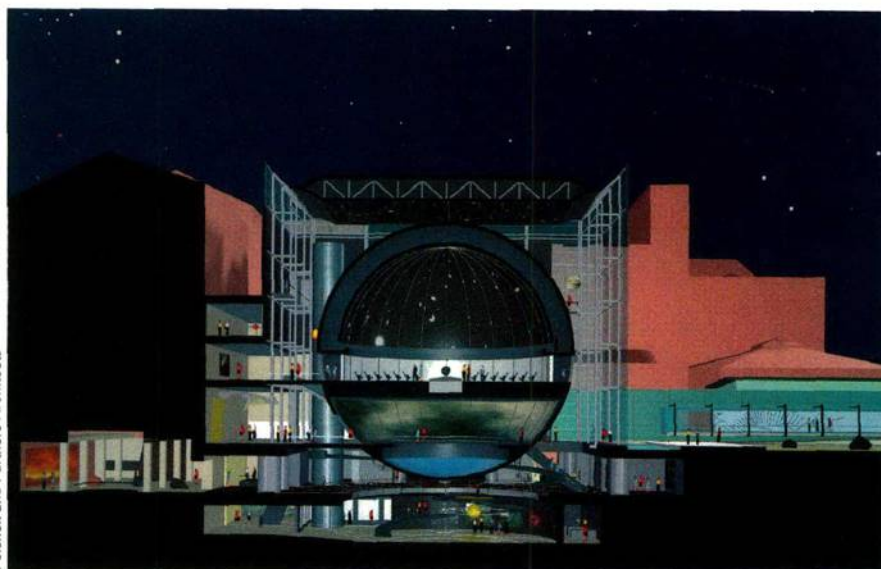
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This cutaway shows the proposed new design of the American Museum–Hayden Planetarium and surrounding exhibits.

LASERIUM Creator Blasts Forum

As creator of LASERIUM Laser Show, which introduced “laser rock-and-roll” to many of the world’s planetaria, I take exception to Claudio Veliz’s deprecatory characterization of all such programming as simply the satisfaction of animal appetites for entertainment, not to mention profit (“Renaissance or Regret,” January 1997).

We have never displaced star show schedules in any of the over 45 venues in which we have performed, and some of the institutions where we have operated depend on the income we provide to augment star show income.

Many, if not most, of the three to four million persons who annually attend laser shows in more than 40 U.S. planetaria would not otherwise have set foot inside and seen the starry sky. We believe we have made and continue to make a valuable contribution to planetaria and the communities they serve by offering creative, generally G-rated technolog-

ical entertainment that doesn’t interfere with the planetarium’s education offerings or its mission. In fact, this programming assists the planetarium’s ability to serve the public, directly with income and indirectly by exposure to a wider audience.

In the process, a lot of people have seen how the sky really ought to look from places like the front of the American Museum–Hayden Planetarium, where they’d never have seen it otherwise. — *Ivan Dryer, Van Nuys, California*

Deltona, Not Daytona

Thank you for including an account of the lunar eclipse seen from Florida (Reader Reports, January 1997). Unfortunately, the site from which we observed it was Deltona, not Daytona Beach. — *Donald Trombino, Deltona, Florida*

Keep the Future in Mind for the Present

It’s not too early to start formulating an ethical policy about our behavior as we so blithely land on other worlds. For instance, in “Back to Mars on All Sixes” (January 1997), Mr. Shibley says that Sojourner carries a “steerable boom tipped with a radioactive source” as well as “onboard lasers which scroll out a pattern along the route just ahead.” Now we feel certain there is no life on Mars that is likely to be injured by

any of our mission artifacts. But what about the future missions when we have no idea who or what inhabits our target planets? Someday there may be planets or moons teeming with colonists and their families, unable to recognize hazardous scientific equipment if they stumble upon it. Shouldn’t we consider our ethical responsibilities to other worlds?

As our space travel capabilities become greater, so surely will the hazardous payloads of the unmanned craft we send. We should give serious thought to our behavior. — *Pam Jones, Los Angeles, California*

The Planetary Society, a private, not-for-profit organization focused on the interests of planetary exploration, sponsored a “name the micro rover” contest in cooperation with the Jet Propulsion Laboratory. Participants were asked to choose a mythological, fictional, or historic (non-living) heroine and describe how she would explore Mars. Three thousand entries were received, and 13-year-old Valerie Ambrose of Bridgeport, Connecticut, provided the winning name.

She chose “Sojourner” in honor of Sojourner Truth, the nineteenth-century slave-turned-abolitionist, because the micro rover is on a journey “to find truths about Mars.”

I believe this should be mentioned so that we, like Valerie, can strive to envision future discoveries on Mars while remaining ever mindful of the courage of those who trudged along murky and perilous paths before us. It may very well be up to Valerie’s generation to fulfill our exploratory and scientific ambitions as we journey to our untold destiny on the frosty sands and tributaries of the Red Planet. — *Kathleen Blakeslee, Carmel, Indiana*

Life on Mars?

Mr. Naeye’s article “Was There Life on Mars?” (November 1996) was particularly timely and noteworthy for me. On September 11, I heard a talk by Ralph Harvey of Case Western Reserve University. He presented arguments that weighed heavily on

the negative side of the possibility of microfossils found on ALH84001. I came away from the talk doubting the validity of the martian meteorite.

After reading Naeye's article, however, I'm not so sure. I feel there needs to be a lot more work done before we can say for sure if life did exist on Mars at one time. — *Martin Stetz, Wickliffe, Ohio*

Many influential philosophers were convinced that life could exist on other worlds and never considered it a major philosophical problem. The discovery of life on Mars would turn the current speculation or hypotheses into fact, but would not touch any of the foundations of our philosophy or science.

However, it could be more of a challenge for some of our religions — Buddhism and Hinduism include the idea of life on other worlds, but Christianity and Islam might find it difficult to accept. God's prophets did not mention television and submarines, so why should they have mentioned Mars?

I do not see any philosophical ramifications of a discovery of life on Mars. There may well be another discovery, probably in the very far future, that would have serious ramifications. The discovery of another intelligent race with its own philosophy might pose a serious challenge to us and our philosophies. — *Rudolf Stolte, Gersthofen, Germany*

The discovery of extraterrestrial life is (or will be) a defining moment in human history.

Perhaps our society is so immersed in science fiction that much of our popular culture has already accommodated itself to alien beings, both benign and aggressive, and the prospect of real fossils from Mars is boring. — *Charles Bonner, Nashua, New Hampshire*

Yes, there exists another civilization in the Milky Way Galaxy: the DNA of its members are called microchips, their heads are called computers, and their bodies are called robots.

Their members are presently taking foot on Earth, which is a small rock orbiting an average star in the outskirts of an ordinary spiral galaxy. The water on the small rock is toxic and dangerous for the planet's species. Presently four of them are leaving the solar system. — *Michael A. Vaccaro, Rome, Italy*

Confirmation of and consensus for the idea of life on Mars will eventually emerge either as a result of further analysis of meteoritic ejecta, or as a result of future surveying trips to Mars. I think that life is an emergent property of complex systems and it doesn't get much more complex than that swirling cosmic soup we look up into at night from our backyards.

— *Jeff Rawlings, Yellville, Arizona*

Articles such as yours are important to those of us in the research community. They help publicize efforts and may also illustrate the benefits to a rather wide range of individuals in society of such research efforts. I hope ASTRONOMY continues to find success in publishing articles that appeal to those with interests in science — it is vital for producing the next generation of scientists. — *Tyler Kokjohn, Lincoln, Nebraska*

Young Astronomers Welcome

I appreciate the hard work the Rockford Amateur Astronomers invested in making Alcon/AstroCon '96 a success. I was especially glad to see that ASTRONOMY highlighted the 1996 National Young Astronomer award winner Mani Mahjouri.

High school students, teachers, and anyone interested in more information, or nominating potential candidates for further awards, may do so by contacting me at 621 W. Main Street, Louisville, KY, 40202-2967, telephone (502) 587-7711. — *Sally Lambert, 105153.2244@compuserve.com*

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- Includes wide-field eyepiece
- Reengineered mount system



8-INCH f/7 \$399⁹⁵

- Lunar/planetary scope
- Tube 57 x 9.5 inches
- Diffraction-limited optics
- Includes high-magnification eyepiece
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- Extremely portable
- Tube 44 x 12.7 inches
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- Includes wide-field eyepiece
- Improved mount system



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Soft case	40
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Meade Barlows:	
#122 2x 1.25"	48
#127 2-3x 1.25"	60
#140 2x 1.25"	80
Starfinder Accy's:	
Dust caps	call
Dec 55	78
Magellan-VII	call

Meade Accy's:

Accy case 50	\$67
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Diagonal 1.25"	42
Diagonal .96-1.25"	28
Diagonal .96-1.45"	43
Diagonal 1.25-1.45"	43
Diagonal 929 2"	100
Epoch2000	call
EP holder 1.25"	25
Finder 8x50	70
Finder 634-6x30	50
Filter set of 4	50
Filter set of 8	100
Filter ND96 1.25"	18

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Ilum 12mm w/cord	\$80
Ilum 12mm w-less	100
Ilum 9mm w/cord	130
Ilum 9mm w-less	150
Lenshood 7/8"	114
Lenshood 10"	124
Lenshood 12"	174
Magellan	call
Nebula 908B	80
Nebula 908N	90
Nebula 911B	100
Nebula 911N	120
Off-axis guider	80
Pictor 208-XT	499

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Piggy brkt 8/10"	\$32
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Vari pol 905	50
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Weight set 10"	94
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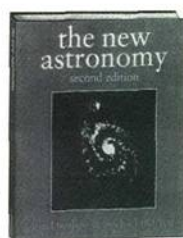


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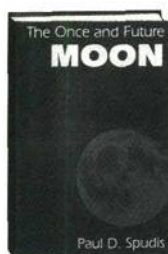
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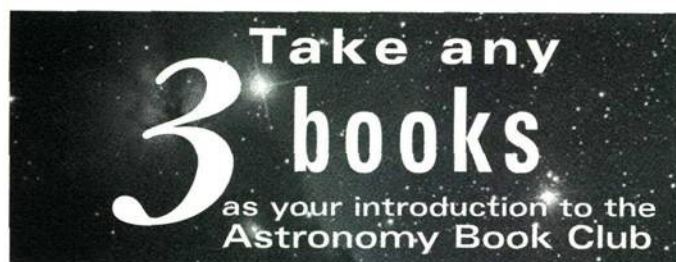
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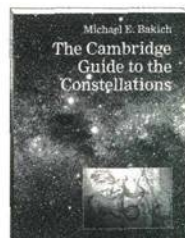
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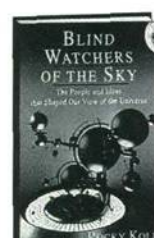
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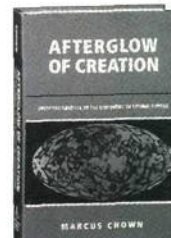
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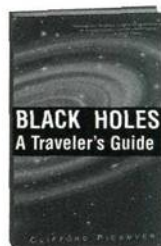
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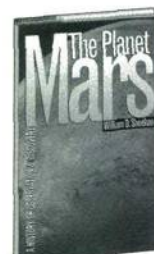
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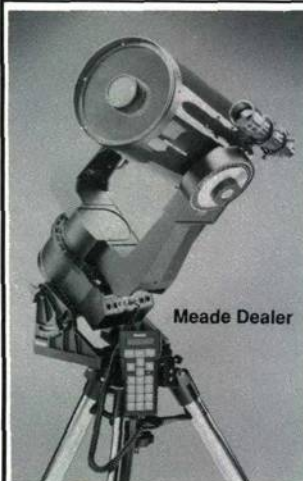
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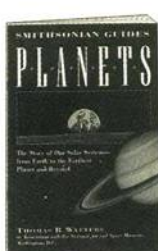
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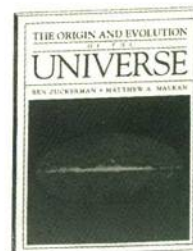
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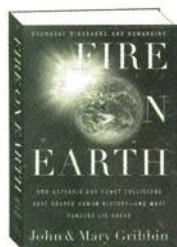
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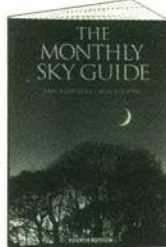
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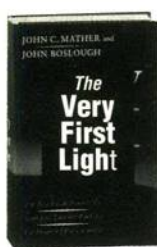
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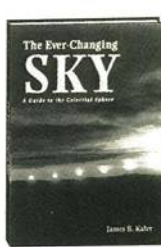
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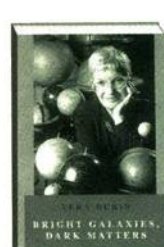
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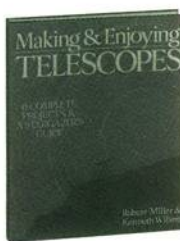
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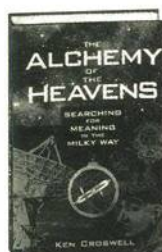
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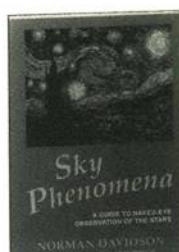
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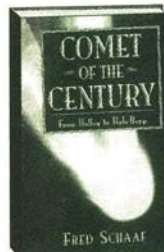
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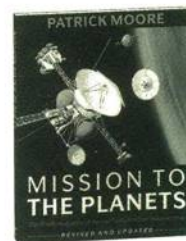
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"Astronomy's too big a field with too much happening. You can't know it all anymore. Can't even read all the papers in your own research area." I recall hearing this comment from a respected professional astronomer at a recent American Astronomical Society meeting. And it's true. So much is happening in so many areas of the field — MACHOs, gamma-ray bursters, the nuclei of active galaxies, planetary atmospheres, the interior of the sun, and black hole theory, to name a few — that it's a dazzling task to sift through everything each month and bring the best of it to you in the pages of ASTRONOMY.

To help us continue to provide the best coverage of a growing field, we proudly introduce our new board of advisors, who will help us make our magazine the very best it possibly can be. Comprised of luminaries in the field, the board will assist us as eyes and ears in many areas. We're sure that many of them are familiar to you, and their influence will gently filter through our pages over the coming months and years.

BUZZ ALDRIN, the second human to stand on the moon, walked in space during the Gemini XII mission before traveling in the lunar module for the historic Apollo XI landing. Born in Montclair, New Jersey, in 1930, he was graduated third in the West Point class of 1951 before serving with distinction in the Air Force in the Korean conflict and then returning to earn a doctorate from the Massachusetts Institute of Technology.

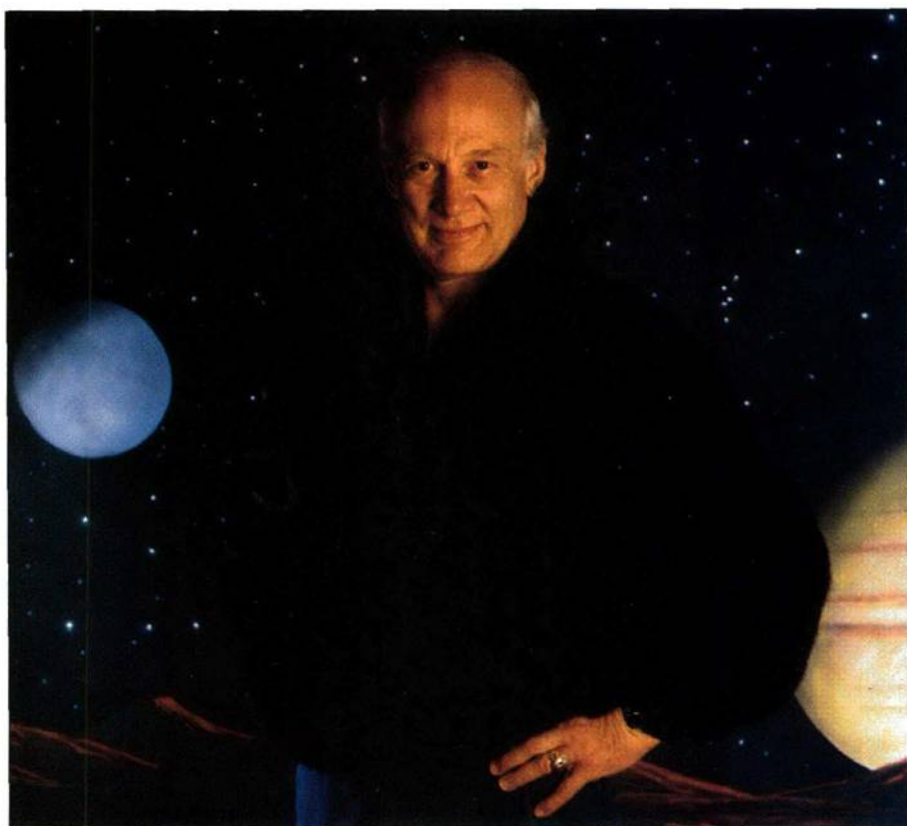
Selected in 1963 as one of the early NASA astronauts, Aldrin's Gemini and Apollo flights delivered 290 hours in space. He has been awarded 50 distinguished medals and citations from various nations, including the Presidential Medal of Freedom. Retired as commander of the Test Pilots School at Edwards Air Force Base in California, Aldrin now explores the potential for space with Starcraft Enterprises, his company, and has just finished a science fiction novel, *Encounter with Tiber*, to be published by Warner Books. He also chairs the National Space Society. Aldrin and his family live in Laguna Beach, California.

TIMOTHY FERRIS is the author of nine books, including the upcoming *The Whole Shebang: A State of the Universe(s) Report*, and the bestsellers *Galaxies*, *Coming of Age in the Milky Way*, and *The Mind's Sky*. A former editor of *Rolling*

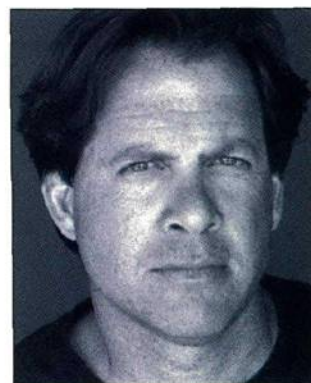
Stone magazine, he is author of more than 100 articles, essays, and reviews in such publications as *Esquire*, *Nature*, *The New Republic*, *The New York Times Book Review*, and *Reader's Digest*. He is a regular contributor to *The New Yorker*, and writes a column for *Scientific American*. Ferris wrote and narrated *The Creation of the Universe*, an award-winning PBS special, and has served as an essayist for *The MacNeil-Lehrer News Hour* and a commentator for National Public Radio's *All Things Considered*.

Ferris produced the Voyager phonograph record, an artifact of human civilization containing music, sounds of Earth, and encoded photographs, that was launched aboard the Voyager spacecraft. He serves as a consultant to NASA on long-term space exploration policy.

A generalist scholar, Ferris has taught in five disciplines at four universities. He is currently emeritus professor at the University of California, Berkeley.



Buzz Aldrin

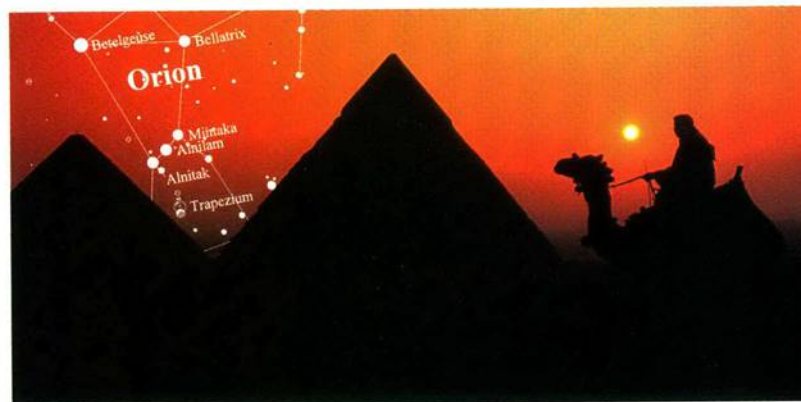


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JOHN S. GALLAGHER III

is professor of astronomy and chairman of the astronomy department at the University of Wisconsin. After earning a bachelor's degree from Princeton and doctorate from Wisconsin, Gallagher held positions at the University of Nebraska, University of Minnesota, University of Illinois, and Northern Arizona University. He has also served as director of Lowell Observatory, an astronomer at Kitt Peak National Observatory, and a vice president of the Associated Universities for Research in Astronomy. He has approximately 125 published scientific papers to his credit.

Gallagher concentrates on understanding how galaxies evolve. What conditions set the rates at which galaxies evolve as they turn gas into stars and change their structures? How do the environments where galaxies are located influence these events? What can the smallest and least massive galaxies tell us? Gallagher and his students are pursuing these questions and others using an array of ground-based instruments and the Hubble Space Telescope. Gallagher also counts as an active interest the many classes of highly evolved single and binary stars. He also spends time assisting the Gemini 8-meter telescopes project and the National Astronomy and Ionosphere Observatory during its major upgrade for the 1,000-foot Arecibo radio telescope.



Jay Gallagher

PAUL HODGE is professor of astronomy at the University of Washington and serves as editor of the *Astronomical Journal*, an official publication of the American Astronomical Society. He was born in Seattle and educated in the East, with a bachelor's degree from Yale and a doctorate from Harvard. He has held research and teaching positions at the

Mount Wilson and Palomar Observatories, the California Institute of Technology, and the University of California at Berkeley before moving to the University of Washington. His research is primarily in the field of galaxies and star formation, but he also works on meteoritics, especially on meteorite craters.

Hodge is author or coauthor of more than 400 published scientific papers and 14 books. Among the books he has produced are *Galaxies*, *The Large Magellanic Cloud*, *The Small Magellanic Cloud*, *An Atlas of the Andromeda Galaxy*, *Galaxies and Cosmology*, and *Solar System Astrophysics*.



Paul Hodge

ANNE L. KINNEY is the project scientist for Education at the Space Telescope Science Institute in Baltimore, Maryland. She is a specialist on the universe outside our Milky Way, and has concentrated on quasars, blazars, active galaxies, starburst galaxies, irregular galaxies, and normal galaxies. She has worked with data collected both from ground-based observatories and orbiting telescopes, and in wavelengths from radio to x-rays. Most recently, she has worked to characterize the spectral properties of nearby galaxies so they can be used as a comparison with the very distant galaxies being observed with HST.

Kinney graduated from the University of Wisconsin at Madison in 1975 and proceeded to earn a doctorate in astrophysics from New York University in 1984. Shortly thereafter she joined the Space Telescope Science Institute as a research associate, an instrument specialist on the telescope's Faint Object Spectrograph, and finally her present position.

She is coeditor of the book *The First Year of HST Observations: Proceedings of a Workshop Held at the STScI*, and is author of nearly 60 scientific papers on galaxies and quasars.



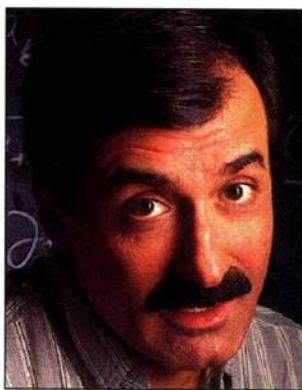
Anne Kinney

EDWARD KOLB, known to most as Rocky, is a member of the NASA/Fermilab Astrophysics Group at Fermi National Accelerator Laboratory in Batavia, Illinois. He is also a professor of astronomy and astrophysics and a member of the Enrico Fermi Institute of the University of Chicago.

A native of New Orleans, Kolb received his doctorate in physics from the University of Texas in 1978. He

conducted research at the California Institute of Technology and Los Alamos National Laboratory, where he was the J. Robert Oppenheimer Research Fellow. He is a fellow of the American Physical Society and serves on the boards of several international scientific journals.

Kolb studies the application of high-energy physics to the very early universe. In addition to more than 150 scientific papers, he is the author of *The Early Universe*, the standard textbook on particle physics and cosmology. His book for the general public, *Blind Watchers of the Sky*, was published by Addison-Wesley in 1996, and it presents the story of the people and ideas that have shaped our view of the universe.



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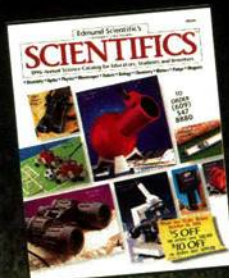
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He also teaches cosmology to non-science majors at the University of Chicago and has given numerous public lectures at Adler Planetarium in Chicago and other sites. Kolb has appeared in television and motion picture productions such as the BBC's *Cosmology on Trial*, the *Great Teachers* video series, and the IMAX film *The Cosmic Voyage*.



Nicholas Allenbernd

ALAN LIGHTMAN, a physicist and a writer, is John E. Burchard Professor of Science and Writing and senior lecturer in physics, at the Massachusetts Institute of Technology. He received his bachelor's degree from Princeton in 1970 and his doctorate in theoretical astrophysics from the California Institute of Technology in 1974. He taught physics and astronomy at Harvard for 12 years before

going to MIT in 1989. During his career, Lightman has made research contributions to theoretical astrophysics and has written two widely used textbooks.

Lightman's literary essays, short fiction, and reviews have appeared in *Granta*, *Harper's*, *The New Yorker*, *The New York Review of Books*, *Story*, and other magazines. Lightman is also the author of many popular books on science, including *Origins*, and *Ancient Light*, an introduction to modern cosmology. His first book of fiction, *Einstein's Dreams*, has been translated into 30 languages. Recent books include the novel *Good Benito* (1995) and *Dance for Two* (1996), a collection of essays.

He is a fellow of the American Physical Society and of the American Association for the Advancement of Science. In 1996 he was elected a fellow of the American Academy of Arts and Sciences. He recently won the 1996 Andrew Gemant Award of the American Institute of Physics, given for linking science to the humanities.

STEPHEN P. MARAN, a 28-year veteran of the space program, is an investigator of stars, nebulae, and comets, who was a 1991 recipient of the NASA Medal for Exceptional Achievement. Press Officer of the American Astronomical Society since 1985, he is a regular guest on the syndicated radio talk show *Capitol Conversation*.

Born in Brooklyn, New York, in 1938, Maran received his doctorate in astronomy from the University of Michigan in 1964. He has worked as an astronomer at

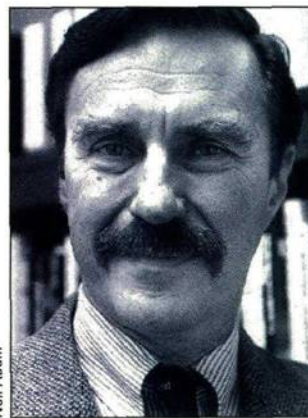


Steve Maran

Kitt Peak National Observatory in Arizona and has taught astronomy at the University of California at Los Angeles and at the University of Maryland. He is the author of more than 300 scientific papers and popular articles in such magazines as *Smithsonian*, *Natural History*, *Scientific American*, and *Popular Science*. He is a contributing editor of *Air & Space/Smithsonian*, the magazine of the National Air and Space Museum.

Maran is a member of three commissions of the International Astronomical Union and is a fellow of the American Association for the Advancement of Science. He is the editor-in-chief of *The Astronomy and Astrophysics Encyclopedia* and has written or edited seven other books since 1964. These include the best-selling *A Meeting with the Universe* and his most recent book, *Gems of Hubble* (coauthored with Jacqueline Mitton), published in 1996 by Cambridge University Press.

Maran and his wife Sally Ann Scott have three children.



Neil Adam

JAMES TREFIL was born in Chicago and received his bachelor's degree from the University of Chicago. He then won a scholarship to Oxford University where he studied before receiving his doctorate in theoretical physics from Stanford University. Trefil has held postdoctoral, visiting, and junior faculty appointments at the Stanford Linear Accelerator Center, European Center for

Nuclear Research (CERN), Laboratory for Nuclear Sciences at MIT, University of Illinois, Fermilab, and Argonne National Laboratory before joining the faculty of the University of Virginia. In 1987 he became Clarence J. Robinson Professor of Physics at George Mason University in Fairfax, Virginia.

Trefil has written extensively about science for general audiences. He is a regular contributor to *Smithsonian*. He has served as a science commentator for National Public Radio and belongs to the Public Information Advisory Committee of the American Institute of Physics. He is also a member of the Ambassador's Advisory Council for selection of Marshall scholars.

His recent books are *Science Matters: Achieving Scientific Literacy* (with Robert Hazen), *A Scientist in the City*, *The Facts of Life: Science and the Abortion Controversy* (with Harold Morovitz), *The Edge of the Unknown*, and *Are We Unique? A Scientist Explores the Complexity of the Human Brain*.

Trefil has published more than 100 papers in professional journals and has made contributions to research in elementary particle physics, fluid mechanics, medical physics, and the Earth sciences. In 1983 he was made a fellow of the American Physical Society. — Dave Eicher □

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For more detailed information on these telescopes, contact a Celestron dealer or Celestron.

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Ganymede Loses an Ocean, Gains a Core

Thanks to a series of flybys by the Galileo spacecraft, planetary scientists can safely assume that Jupiter's Ganymede, the largest moon in our solar system, doesn't possess a subterranean ocean like its cousin Europa might have. Astronomers ventured that Ganymede might harbor an ocean based on preliminary results from an encounter on June 27, 1996. Galileo had detected evidence of a magnetic field around the moon, leading some to speculate a subsurface layer of salt water might exist.

But during a December press conference that showcased findings from a September 6 flyby, team scientists attributed the field, which is $\frac{1}{40}$ the strength of Earth's, to the presence of a molten iron core between 250 and 800 miles in diameter. That such a molten core still exists in what should be a cold, 4.6-billion-year-old moon, has planetary scientists scratching their heads for an explanation.

One guess is that Ganymede was much closer to Jupiter at one time in its history before slowly migrating out to its current distance of 665,000 miles. A closer orbit would have put the satellite under greater tidal stress, flexing the moon's shape to keep its core molten. Tidal flexing makes Io, the closest large moon to Jupiter, the most volcanically active piece of real estate in the solar system.

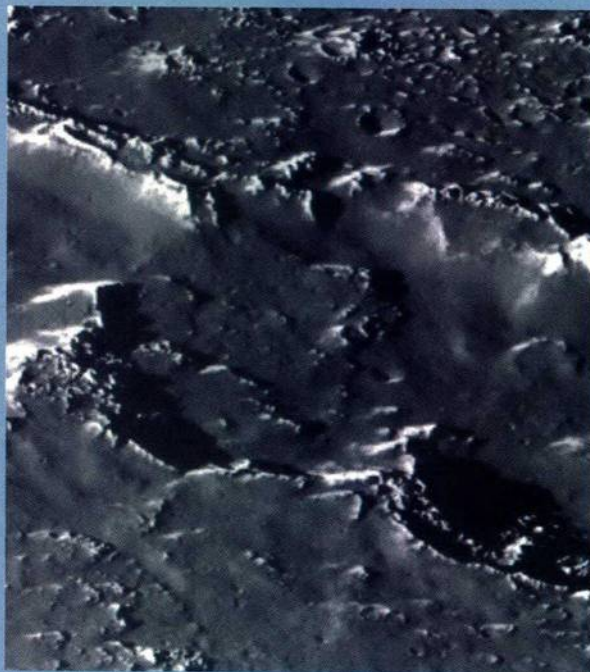
Ganymede presently orbits Jupiter at $2\frac{1}{2}$ times Io's distance from the planet.

Besides detecting a core, Galileo scientists were able to map out the rest of Ganymede's internal structure, thanks to analyzing the spacecraft's change in motion as it flew by the 3,300-mile-wide jovian moon. Surrounding the core is a rocky silicate mantle, which in turn is topped by a layer of ice 500 miles deep.

Zeroing In on the Hubble Constant

How fast is the universe expanding? The debate surrounding this rate, known as the Hubble constant, has been contentious over the years, with some astronomers arguing vociferously for a value of 80 to 100 kilometers per second per megaparsec (one megaparsec equals 3.26 million light-years), while others argue with equal passion for a value as low as 50. The gap has narrowed in recent years. In late 1996, two teams using the Hubble Space Telescope seemed to be converging on a Hubble constant somewhere between 55 and 75.

Two independent groups have just weighed in with a value that splits the difference. In the December 10, 1996, *Astrophysical Journal*, Adam Riess, William Press, and Robert Kirshner of Harvard University report a Hubble constant of 64



NASA/JPL

Last November, Galileo trained its camera on Callisto, the most distant of the four large moons that orbit Jupiter, returning pictures 100 times sharper than the best Voyager photos. Part of a chain of impact craters — formed when a fragmented object similar to Shoemaker-Levy 9 hit the surface — dominates the 8-mile section shown at top. Taken from 974 miles away, the image shows craters as small as 400 feet across. Although Callisto is heavily cratered, scientists were surprised at the lack of small craters, suggesting that some process obliterates small-scale features on the moon.

A four-frame mosaic shows the ancient, 1,000-mile-wide impact structure Asgard (above), which consists of a bright central zone surrounded by discontinuous rings. Large objects continued to strike Callisto after Asgard formed, creating numerous craters. The very young, bright-rayed crater Burr lies in northern Asgard.

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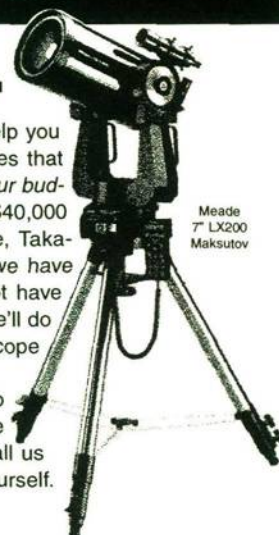
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based on their analysis of 20 Type Ia supernovae in distant galaxies. Type Ia supernovae occur when white dwarf stars explode. These celestial beacons can be seen at immense distances, making them ideal for this kind of research. The Harvard group has factored in the dimming due to dust to obtain the most reliable distance measurements yet to the faraway host galaxies.

The other group, led by Duncan Forbes of Lick Observatory, reports its results in the December 1996 *Astronomical Journal*. This group used HST to identify 1,300 globular clusters orbiting the giant elliptical galaxy NGC 5846. By comparing the luminosity of NGC 5846's globulars to those in the Milky Way, the group measured a distance of about 95 million light-years, which yields a Hubble constant of about 65.

"I truly believe that scientific historians will look back at 1996 as the beginning of the endgame for measuring the Hubble constant," says Riess. A Hubble constant of 65 implies a 14-billion-year-old universe, give or take a couple billion years. Riess notes that several groups are using Type Ia supernovae to measure distances to galaxies that are so far away that astronomers will be able to determine how fast the universe was expanding in the distant past, which will enable them to calculate how long ago the Big Bang occurred. "Stay tuned, in the next two or three years we will likely have a final value for the age of the universe," says Riess.

CLYDE TOMBAUGH (1906–1997)

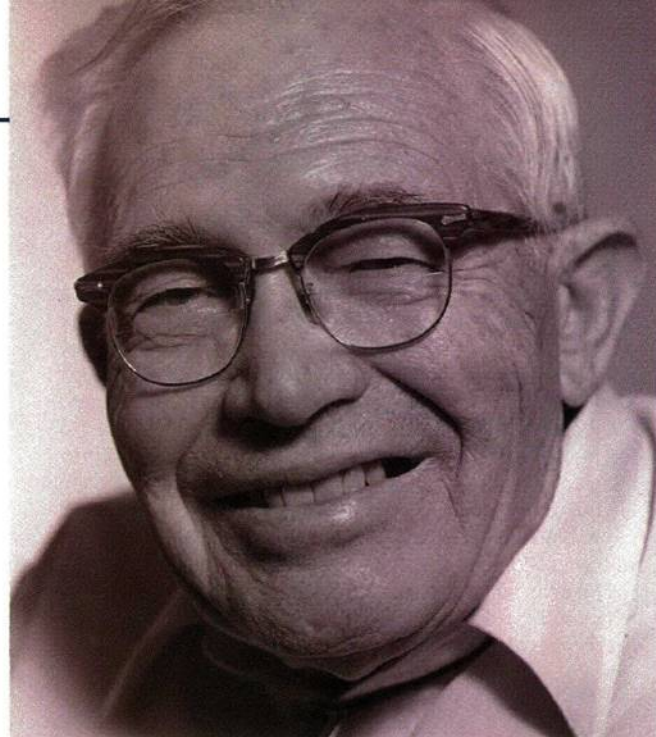
Some discoveries remain forever linked to their discoverers. Such is the discovery of a new major planet.

Clyde William Tombaugh, the discoverer of Pluto, was the only 20th century member of this highly exclusive club, whose other members were William Herschel and Johann Gottfried Galle. Tombaugh died at age 90 on January 17.

Tombaugh was in his early 20s, a strong-bodied, agile-minded farmer from Kansas with an interest in astronomy, when his life became inextricably entangled in the search for Percival Lowell's "Planet X." On his father's Kansas farm Tombaugh had built his own 9-inch reflector, using part of a cream separator as its base; another component consisted of the crankshaft from his father's 1910 Buick. He used this telescope to sketch Mars and Jupiter, and sent the drawings to the Lowell Observatory in Flagstaff, Arizona, for comment, where they still reside.

He could not have known then that the observatory founded by Lowell in 1894, originally to search for life on Mars, was facing a crossroads in its existence, having just resumed the quest for Lowell's somewhat chimerical Planet X — a frigid world beyond Neptune, which Lowell attempted to locate mathematically from small perturbations in the motion of Uranus.

In 1929, the observatory had acquired a new photo-



R. Sterling Trantham

graphic telescope, and Tombaugh was duly hired to carry out the search. Director Vesto M. Slipher thought that, despite his lack of formal training, he would probably prove more reliable "than the highly trained variety" of astronomer.

However, Tombaugh soon became skeptical about the usefulness of Lowell's mathematical predictions. If the planet was to be found, he concluded, it would have to be because of his own thoroughness. Clyde took great pride in the method he devised — photographing the sky around the point where the possible planet would be at opposition; it would then be moving retrograde most rapidly, so it would betray its distance immediately by its parallax.

Of course, Tombaugh eventually succeeded brilliantly, finding "Lowell's planet," as it was at first called, on February 18, 1930; it lay near Delta Geminorum, only six degrees from one of Lowell's positions.

Pluto, as the planet was officially named, proved

not to be even close to massive enough to have caused the perturbations of Uranus used by Lowell in his calculations. Thus the fact that Tombaugh found it lurking near where Lowell had predicted was sheer coincidence — rather like Columbus' landfall in the New World while setting course for India.

After the discovery of Pluto, Tombaugh continued the daunting search for other possible planets. By 1943 he had searched 70 percent of the sky visible from Lowell Observatory. He found no planets; there were none to be found. Recent analysis of Pioneer and Voyager spacecraft trajectories has indeed confirmed Tombaugh's negative result: There are no large masses out to very great distances from the sun.

In recent years, some astronomers have suggested that Pluto itself should be demoted; instead of enjoying major planetary status, it ought to be regarded as only the largest of a host of smaller but similar objects located in the so-called Kuiper Belt

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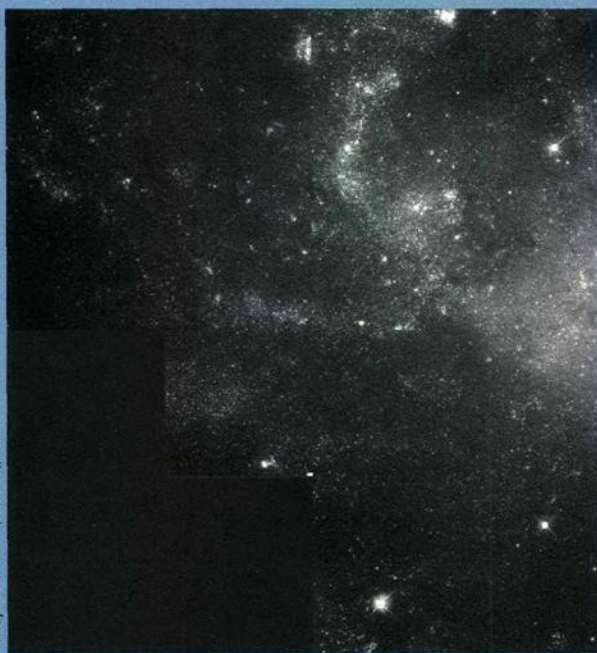
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Astronomical Society of the Pacific

Nancy Silbermann (Caltech), et al.



Kim Zussman



In a continuing effort to determine the expansion rate of the universe, also known as the Hubble constant, a team of astronomers is using the Hubble Space Telescope to measure the distances to relatively nearby galaxies. In the most recent result, the team used Hubble to zoom in on 80 Cepheid variable stars in the barred spiral galaxy NGC 925 in Triangulum. By observing how the Cepheids brightened and faded, the team measured a distance of 30 million light-years. Although NGC 925 is too close to Earth to determine the Hubble constant, astronomers can use the galaxy to calibrate the distance to galaxies much farther away.

beyond Neptune. Tombaugh always responded good-naturedly to these suggestions. "Pluto started out as the ninth planet. For 14 years, I combed two-thirds of the entire sky down to 17th magnitude... I did the job thoroughly and correctly. Pluto was your last chance for a major planet."

A by-product of Tombaugh's planet search was the discovery of what he called the "Great Perseus-Andromeda Stratum" of galaxies, roughly 4,000 asteroids, two comets, one nova, five open star clusters, one globular cluster, and 29,548 galaxies. He was not quite happy at Lowell, though he always had fond memories of drawing Mars with Earl C. Slipher.

He left in the 1940s to do research on optical guidance systems for rockets at White Sands, New Mexico, but returned briefly in the 1950s to search for natural satellites of Earth and the moon (he found none; again, there were none to be found). Finally, he went on to set up the planetary patrol at New Mexico State University in Las Cruces — among his assistants there were Chick Capen, who later became another leading Mars observer at Lowell, and Brad Smith, the imaging team leader for the Voyager 1 and 2 missions to the outer planets.

Instead of retiring to Olympian aloofness, as might have been expected of the sole living discoverer of a new planet, Tombaugh always remained accessible to amateurs, and generously shared detailed advice about observing in count-

less letters written in long hand. Though bowed with kyphosis, an abnormal backward curvature of the spine, he traveled widely until his last year or two when his health finally began to fail. He could always be counted on for his sense of humor and audacious puns.

Wherever he went, he was thronged by amateurs seeking a "little touch of Tombaugh in the night." In later years he seemed to grow reconciled to the fact that he would always be chiefly remembered for the momentous discovery he made in 1930; at least he never seemed to tire of recounting the story, which he must have told thousands of times.

"He has won what no mortal man has won before," the Greek poet Pindar once sang of one of the champions of the Olympic games. Tombaugh won from the darkness an icy world on the fringes of the solar system; now he is gone we have all lost a wonderful inspiration and a friend. — William Sheehan

Astronomers Find New Ion

Nothing satisfies a scientist more than when observation confirms theory. In 1961, astronomers predicted the existence of the H_3^+ ion in interstellar space. This molecule consists of three hydrogen atoms missing one electron (in other words, three positively charged protons and two negatively charged electrons), hence the positive electric charge. Astronomers suspected that H_3^+ plays a

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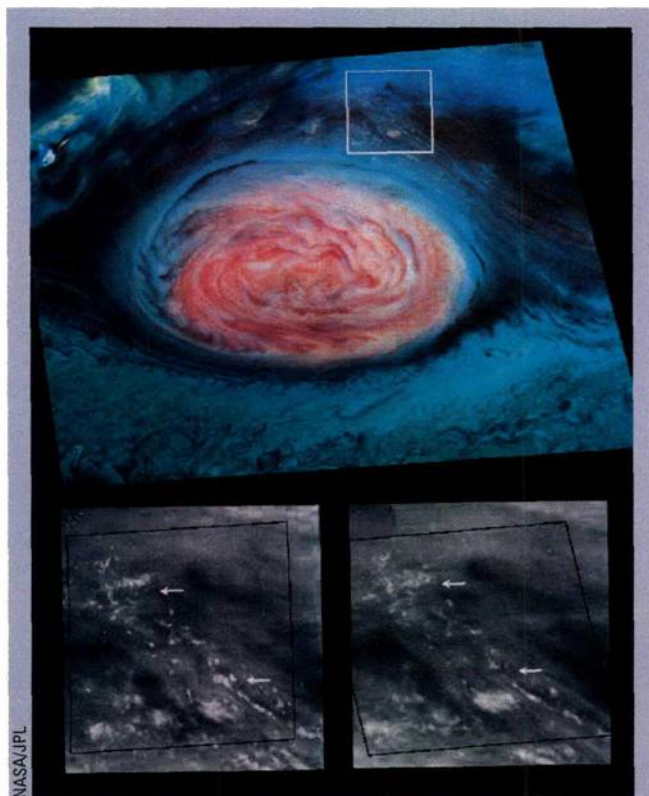
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vital role in the chemistry of interstellar gas clouds, which are the places where stars are born. Unfortunately, H_3^+ gives off such weak radiation that astronomers had spent 15 fruitless years looking for it in deep space. Until now.

In the November 28, 1996, *Nature*, Thomas Geballe of the Joint Astronomy Centre in Hawaii and Takeshi Oka of the University of

Chicago report finding the spectral signature of H_3^+ by looking at two different interstellar clouds. They found the ion using the United Kingdom Infrared Telescope situated atop Mauna Kea.

Astronomers think H_3^+ initiates a series of chemical reactions that ultimately produces some of the more exotic molecules observed in interstellar gas clouds. " H_3^+ controls the entire chemistry of these



Galileo has finally nailed what atmospheric scientists were sure existed on Jupiter: thunderstorm super-cells. Such storms were indirectly detected as flashes on Jupiter's nightside in pictures taken by the Voyager spacecraft during their 1979 flybys. Galileo images taken last summer show mighty thunderstorms circulating around Jupiter's Great Red Spot at 300 miles per hour. Two frames show how the 20-mile-wide cells move and evolve over 70 minutes' time. False colors show high clouds, like thunderstorms jutting 20 miles above Jupiter's cloudtops, as white. Pink features are light, intermediate-range clouds, while the dark blue reveals clouds deep in the jovian atmosphere.

Quickie Brown Dwarfs

In the November 21, 1996, *Nature*, Edward Rosenthal and two Harvard colleagues report a novel way to detect brown dwarfs. Because these substellar objects are cooler than stars, they contain certain molecules, such as methane, that burn up in stars. To possibly bag a brown dwarf, take an image in the methane band and subtract it from a broadband image. Using this method, Rosenthal and company found Gliese 229B — the only confirmed brown dwarf — in less than two minutes of integration time.

Remembering Astronomy Papers

Astronomers are fully aware of the maxim "publish or perish." But how long after a paper is published do other astronomers continue to cite it? In the November 1996 issue of *Publications of the Astronomical Society of the Pacific*, Kitt Peak astronomer Helmut Abt reports his analysis of 165 papers published in the *Astrophysical Journal* in 1954. Abt found that papers have an average half-life of 29 years. Observational papers have a longer half-life (35 years) than theoretical papers (22 years). Because the number of published papers is growing so fast, Abt predicts that papers published today will have a much shorter half-life.

NASA Revisits the "Face"

The Mars Global Surveyor spacecraft will image the infamous "Face on Mars" shortly after it begins mapping the martian surface in 1998 (the spacecraft arrives at Mars in September 1997). NASA will post the pictures on Global Surveyor's Web site (<http://mgs-www.jpl.nasa.gov/>) as soon as they are received. The high-resolution pictures are expected to show details as small as 10 feet across, ten times better than the best Viking images.



Computerized Telescope On-line

The University of California at Berkeley's Katzman Automatic Imaging Telescope is up and running at the Lick Observatory in southern California. Armed with a CCD camera, the 30-inch computerized telescope primarily searches for exploding stars in other galaxies. Other programs will allow students to hunt for asteroids and comets.

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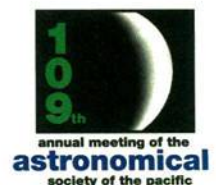
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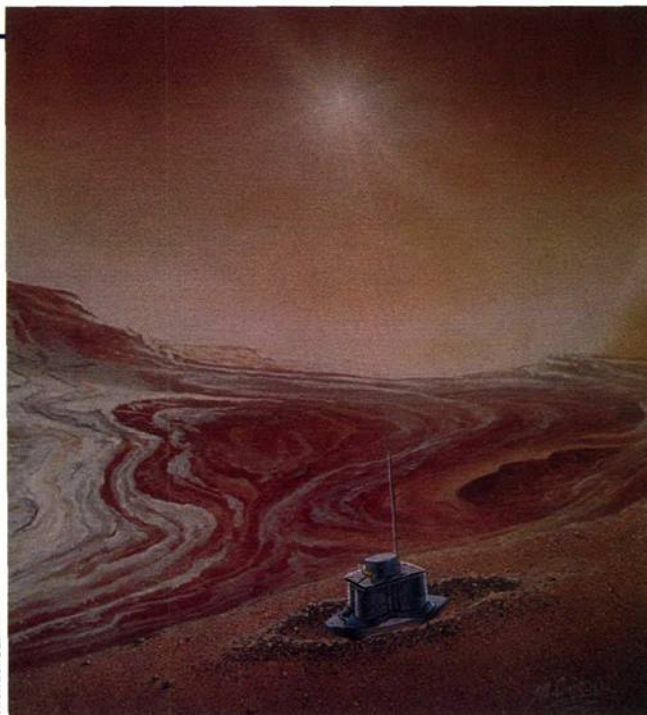


clouds, and the chemistry in turn controls how fast the gas can cool and collapse to form stars," writes University of Nevada at Las Vegas astronomer Stephen Lepp in *Nature*. Geballe, Oka, and other astronomers will now go out and measure how much H_3^+ exists in these clouds, which will help astronomers better understand star formation.

NASA Networks Mars

Two tiny space probes bound for Mars in 1999 will bring a new meaning to the term "networking." Dubbed Deep Space-2, the probes will land at differ-

Michael Carroll



ent sites, enabling scientists to survey weather and mineralogy over a large area of Mars' southern

hemisphere. If all goes according to plan, the two will be followed by whole networks of spacecraft that

Deep Space-2 greets a martian sun dog near the south pole of Mars. It's one of two probes slated to burrow into the Red Planet's surface in 1999.

might monitor the surface of Mars and other planets in our solar system.

Explains Microprobe Chief Engineer George Powell, "It's almost impossible to understand the weather in Moscow by having a thermometer in Pasadena. [Probe networks] will enable us to have a global understanding of the planet."

Deep Space-2 gets a lift to Mars courtesy of the larger Mars Surveyor Lander. That lander will make a soft-landing near the south pole of the Red Planet to study martian climate. Not so the little microprobes — they will crash-land about 120 miles north of the lander.

Each five-pound craft bails out of the Surveyor taxi several days before atmospheric entry and hits the surface at 200 meters per second (450 miles per hour). The basketball-sized craft have no landing system and must withstand an impact force of 80,000 times Earth's gravity.

On impact, each probe splits into two parts. A forebody digs in to a depth of up to six feet to chart thermal properties of the martian soil. The aft body rests on the surface to deploy an antenna that will relay its own meteorological data as well as data from the forebody, attached by a six-foot cable. If their batteries hold out, the probes could send information back to Earth for up to two weeks. —

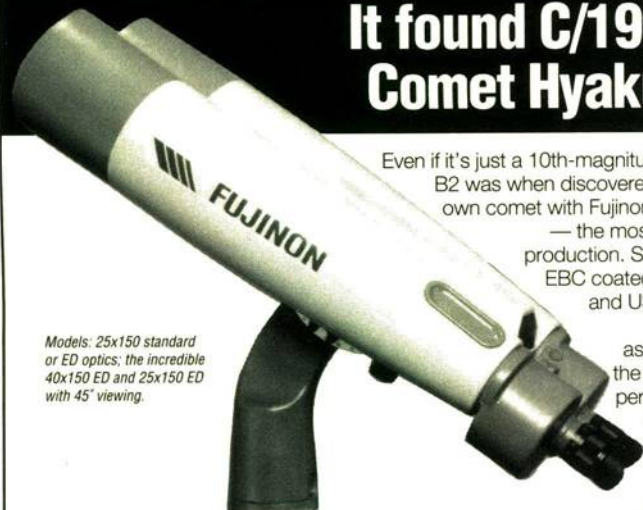
Michael Carroll

Laurent Drissen and Yvan Dutil (CFHT) and NASA



The ultra-sharp eye of the Hubble Space Telescope reveals a giant star-forming region in NGC 2363 (right), a faint, irregular galaxy some 10 million light-years away. A ground-based photo of NGC 2363 appears at left. The bright star at the top of the fishhook-shaped cloud of gas belongs to a rare class called Luminous Blue Variables. LBVs are the most massive stars in the universe, weighing in with a mass of 30 to 100 suns. LBVs have been likened to geysers because they undergo periodic eruptions. By comparing Hubble photos with previous ground-based photos, astronomers discovered that this star grew 40 times brighter within three years. Hubble also reveals two star clusters. At the top is one that is five million years old — supernovae and stellar winds have blown away the gas. The other cluster (bottom center) is only two million years old, and is still enshrouded in a cocoon of gas and dust.

It found C/1996 B2, Comet Hyakutake



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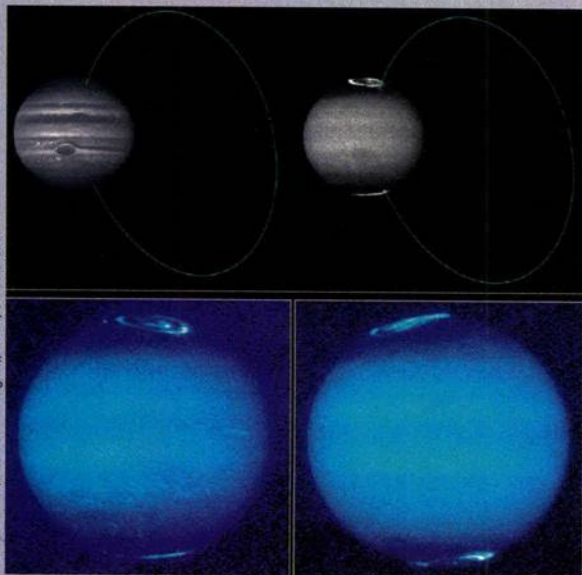
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John Clarke (Univ. of Michigan), et al., and NASA



Earth's aurorae aren't too shabby, but a Jupiter aurora would be a dazzling sight to behold. Because Jupiter rotates faster than Earth and has a much stronger magnetic field, Jupiter's light shows are 1,000 times more powerful than Earth's. Astronomers can track daily changes in Jupiter's aurorae with Hubble Space Telescope images such as these. The black-and-white images show the location of an electrically charged "flux tube" that connects Jupiter's large moon Io with the planet. Particles ejected by Io's frequent volcanic eruptions travel along the flux tube to the planet's magnetic poles. The photo on the left was taken in visible light, the one on the right was taken in ultraviolet light 15 minutes later (Io is invisible because it is faint in ultraviolet light). When particles from Io smash into Jupiter's upper atmosphere, they react with hydrogen gas and cause it to fluoresce. Both color images were taken in ultraviolet light. They reveal how Jupiter's aurorae change in brightness and structure as the planet rotates. If you look closely, you can tell that Jupiter's magnetic field is slightly offset from its spin axis.

Debating the Diffuse Interstellar Bands

Everything from buckyballs to alien bacteria has been proposed as a culprit in an astronomical mystery — the absorption of starlight causing "diffuse interstellar bands," or DIBs. Although Peter Sorokin and James Gtownia are not astronomers, they think they have the puzzle at least partially solved. The laser spectroscopists from the IBM

Watson Research Center in Yorktown Heights, New York, say that hydrogen, the universe's most abundant substance, is the light thief. The astronomical community seems wary, but curious.

Some 270 DIBs have been identified, with new ones constantly being discovered. Interstellar ringed-hydrocarbons get the most votes as the light absorbers. Every DIB would require a distinct hydrocarbon absorbing at

a distinct wavelength. The Sorokin/Gtownia model has hydrogen absorbing visible light and ultraviolet light simultaneously. The combination punch would cause absorption that matches about 70 of the sharpest 130 DIBs.

One impromptu test of this idea may have been analyzed since this issue of *ASTRONOMY* went to press. If Sorokin and Gtownia are right, ultraviolet emission should be seen in the so-called Red Rectangle region of our galaxy. Just days before the launch of the space shuttle Columbia last November, Berkeley's Mark Hurwitz heard about the hydrogen hypothesis. Hurwitz had the ORFEUS-SPAS ultraviolet telescope aboard. "He sent e-mail," Sorokin says, "saying he would arrange to look at the Rectangle. So we got a ticket on the bus at the last minute. We were delighted — what a lucky chance." — *Steve Mirsky*

Do Crater Chains Exist on Earth?

Some planetary scientists think Earth may have been bombarded in the past by fragments of asteroids or comets, creating regularly spaced rows of impact craters. Two such possible crater chains have been identified, but a new study claims that these structures, if indeed they are all impact craters, must have formed differently.

Crater chains form when an asteroid or comet gets pulled apart, or tidally disrupted, by the gravity of a much larger body. That's what happened to comet Shoemaker-Levy 9 in 1992, when Jupiter sepa-

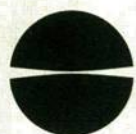
rated the comet into a train of more than 20 large fragments that smashed into Jupiter two years later.

The Voyager spacecraft imaged three crater chains on Jupiter's moon Ganymede and 11 on Callisto. And two apparent crater chains exist on Earth's moon: the Davy and Abulfeda chains. Both are several hundred million to a few billion years old.

The largest suspected crater chain on Earth stretches from eastern Kansas through Missouri into southern Illinois. It consists of eight circular features, two of which are known impact craters about 300 million years old. Another possible chain lies in northern Chad and features a 360 million-year-old crater named Aorounga and two nearby structures that have yet to be verified as craters.

William Bottke, Jr., and Stanley Love of Caltech and Derek Richardson of the University of Washington have recently modeled the tidal disruption of objects by the moon and Earth to estimate how often each causes crater chains on the other. They conclude that the moon should show roughly 10 times as many crater chains as Earth. If two younger than 360 million years exist on Earth, then about 20 young crater chains should be seen on the moon. But none are.

The researchers conclude that the crater chains on Earth, if real, were not produced by asteroids or comets disrupted by lunar tides. They are more likely secondary craters from an unseen or unrecognized large terrestrial crater. □



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- The **Star Hopper™ 6" and 8"** primary mirrors are housed in 8" and 10" ID tubes respectfully. The oversized flat black anti-reflective painted tubes reduce light scatter and tube currents. These features increase image contrast and improve "seeing" when viewing planets and the Moon.
- The **V-Spectrum LTM Optical System** features a unique molded **Pyrex** mirror, **multi-coated** for increased reflectivity, that provides superior optical and thermal qualities and it is mounted on the **Pinnacle** mirror cell.
- The **V-Spectrum LTM (Low Thermal Mass)** mirror is manufactured and figured to reach the optimal marriage of weight to optical surface resulting in a mirror with 40% less mass than traditional mirrors. Reducing the mass lowers the "cool down" period required to bring the mirror to ambient temperature and leaves more time for observing. An optional fan can be placed behind the **Pinnacle** mirror cell to create a laminar flow of air over the **V-Spectrum LTM** primary mirror to optimize the mirror for planetary and high power observations..
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Firstscope 114 Its 910mm focal length (f/8) optical system is housed in an aluminum tube. This high quality yet economical telescope is made in a modern, high quality telescope factory in China to **Celestron's** specifications.

The equatorial mount is stable and includes setting circles in both axes as well as slow-motion cables in both axes for easy tracking. The wood tripod is adjustable in height and includes an accessory tray.

Standard accessories include a 5x24 Finderscope, 1 1/4" Focuser (with a .96" adapter), 20mm H-.96" Eyepiece (46x), 4mm SR-.96" Eyepiece (228x), 2x Barlow Lens -.96"

A **Firstscope 114 Deluxe** model is available which replaces all .96" accessories with two high quality 1 1/4" eyepieces – 25mm SMA (36x) and 10mm SMA (91x). The 1 1/4" accessories give you sharper views, a wider field of view and better eye relief.



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For more detailed information on these telescopes, contact a Celestron dealer or Celestron.

Carl Sagan

Remembered

A Scientist's Reflections

Carl Sagan was perhaps best known for his interest in exobiology (the search for and study of life elsewhere in the universe) and for his enthusiastic portrayal of other worlds, coincident with the most exciting period of planetary exploration by robotic spacecraft. However, I would argue that his most important, most persistent, and most difficult goal was to convince non-scientists of the crucial need for critical thinking (including the scientific method). Sadly, we live in a society where many people believe in astrology, where many think that the plot of the movie "Independence Day" is entirely plausible, and where elementary concepts of probability (as in their use in DNA evidence) are not understood. Carl was not alone in his efforts to bring the power of scientific reasoning to the public, but devoted more effort than most and reached a larger segment of the population. If I could name but one legacy that would best acknowledge him, it would be a stronger commitment of the scientific community to combat irrationality.

I can attest through personal experience that Carl could inspire. The first planetary science course I took was from Carl (at Cornell University in the early 1970s). He encouraged me to turn my term paper into a published journal article, which I did. I stayed up to watch his first appearance on the Johnny Carson show and I spent time on occasion in later years talking with him at length, usually about Titan or about the early Earth (which may have something in common!) Carl had the remarkable capacity to recognize key issues in a scientific problem, or connections among problems that others missed. Usually some issue about the origin or existence of life here or elsewhere was at hand or lurking nearby in his thinking.

Many scientists treated Carl and his activities with some disdain or disinterest. I can think of several reasons for this, but I will focus on two. The first is the strong emphasis on personality rather than scientific substance in his best known effort, the TV series *Cosmos*. I believe that this was inevitable and not altogether bad. TV turns people into personalities (if they have what it takes) independent of whether they have something of substance to say. Many TV news readers know little about the world and many TV weather "personalities" know little about what causes weather (in fact, few people do). But Carl had something of substance to say, said it well, and usually knew very well what he was talking about. In becoming a personality, someone to whom people could relate, he was most effective.

The scientific reaction to Carl Sagan tells us something about the schizophrenic view the scientific community has of itself. We portray ourselves as searchers for an understanding of nature, with everything else

secondary. We are thus suspicious of those who seek or accept the limelight as popularizers or researchers since this necessarily reduces their commitment to the quest. But in fact, most scientists rely on taxpayers for their livelihood. Basic science, including unraveling the mysteries of the universe, may have no tangible payoff at least in the short term. Scientists have an obligation to engage the public, to explain to them why it is worth their dollars. Readers of this magazine may not need persuading that space is fascinating, but many others need to be made aware of how remarkable the universe is. Carl did this extremely well and the scientific community should be immensely grateful. Carl's gift was rarer than the gift of a great researcher and his impact has been greater than many a great researcher.

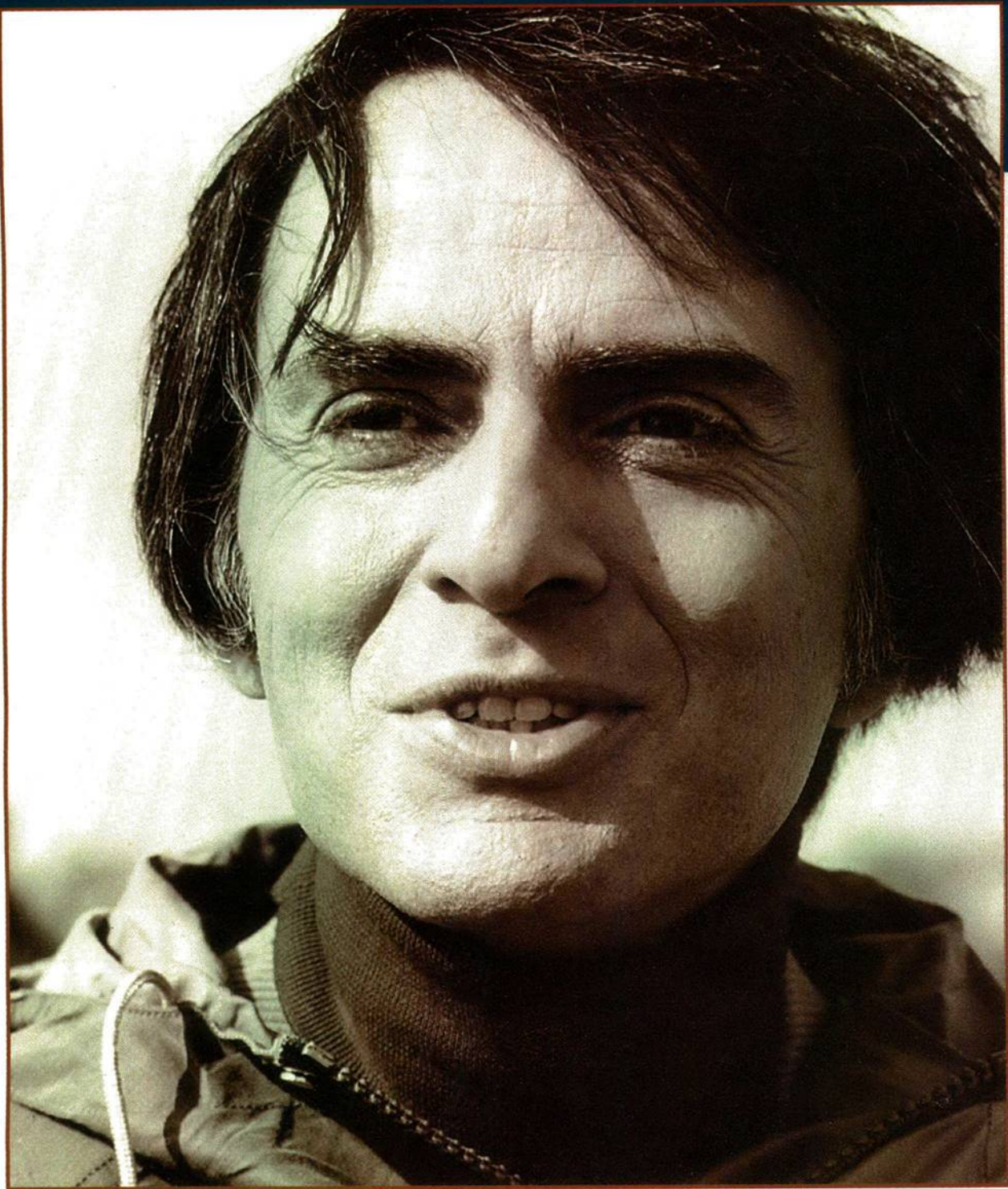
Dave Stevenson is a professor of planetary science who works on the origin, evolution, and structure of planets, including Earth. He earned his Ph.D. in physics at Cornell in 1976 and has been the George van Osdel Professor of Planetary Science at California Institute of Technology since 1980.

A Poet's Reflections

In 1971, I first heard Gustav Holst's powerfully melodic "The Planets," and I thought how sad it was that artists felt the need to deny the reality of the planets, to pretend they were gods and goddesses in order to admire them, to completely ignore their authentic natural beauty. The real planets fascinated me, and I wanted to learn more about them and celebrate them in art. When I entered Cornell's MFA program that year, I began writing *The Planets: A Cosmic Pastoral*, a suite of scientifically accurate poems about the planets.

At that time, Carl Sagan had published only one book — *Intelligent Life in the Universe* — which he co-authored with I.S. Shklovskii. I found a kindred spirit in its pages, and so asked Carl to be the technical advisor on *The Planets*, and he was happy to oblige. I discovered Carl to be a shy, modest, easily enthused scientist with a rompy mind and boundless curiosity. He opened his lab and library to me, and we had wonderful gabfests. In the early 1970s, it was possible to learn almost everything humans knew about the planets, and with his help, I did.

A little later, Carl played a vital role on my doctoral committee. Unfortunately, most colleges foolishly demanded (and still do) that students choose between the Humanities and the Sciences, but I always felt that the universe wasn't knowable from any one perspective. I craved the truths of Science and also the truths of the Humanities. Having Carl on my committee legitimized my interdisciplinary passion, and also made me feel less alone in my own explorations.



Bill Ray

Increasingly, we became friends, and some of my fondest memories are of long ago, flying with him and his second wife Linda and novelist Paul West, to Cocoa Beach for launches or to the Jet Propulsion Laboratory for fly-bys. I hold extremely fond memories of the early days and innocence of the space program, which Carl promoted with candor and curiosity. During those years, he commissioned two poems from me: an old fashioned love ode — but to an extraterrestrial — which I titled “Ode to the Alien” and a poem about “Nuclear Winter.” That was quintessentially Carl: someone who relished seeing things from as many perspectives as possible.

So much happened in Carl’s life after that—a landslide of fame, a third marriage, two more children, many books and projects—but I find my warmest memories of him are from his (and my) early days at Cornell, when he was a badly combed scientist with a world of ideas, and I was a fledgling poet. □

Diane Ackerman, a distinguished poet and prose writer, has frequently published in The New York Times, The New Yorker, National Geographic and Parade. Her most recent books include A Natural History of the Senses and The Moon by Whale Light.



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The Strange New PLANETARY ZOO

The dozen or so planets found orbiting solar-type stars have turned planet formation theory on its head.

by Robert Naeye

Paintings by Lynette Cook

For centuries, the question of planets outside our solar system was rife with speculation. Astronomers could cite any number of indirect pieces of evidence that planets are sprinkled all over the Galaxy. But without any hard evidence, there was always a nagging element of doubt.

In 1991, radio astronomers Alex Wolszczan and Dale Frail discovered planets orbiting a type of collapsed star known as a pulsar. But that still left open the question of whether planets commonly orbit stars similar to the sun — a question of paramount importance to those interested in extraterrestrial life.

Then on October 6, 1995, everything changed. On that date Michel Mayor and Didier Queloz of the Geneva Observatory in Switzerland announced the discovery of a planet orbiting the solar-type star 51 Pegasi. Just three months later, Geoff Marcy of San Francisco State University and colleague Paul Butler of the University of California at Berkeley announced two planets of their own. Knowing that he and Marcy had just started analyzing their mountain of data, and that other groups were closing in as well, Butler confidently predicted: "Within one year, more extrasolar planets will be known than there are planets in our solar system."

Butler's prediction turned out to be remarkably prophetic. One year later, astronomers have detected nearly a dozen planets orbiting other solar-type stars, the exact number depending upon which objects one chooses to count as planets. But astronomers are not content to rest on their laurels. "Nature is very rich, much richer than we had thought at the beginning," says Queloz. "We have to find more objects to better understand where we are."

The Hot Jupiters

Although each extrasolar planet has its own unique characteristics, the ones discovered to date orbiting solar-type stars can be conveniently lumped into three families. The 51 Pegasi planet belongs to a family that stunned the astronomical community: Jupiter-mass planets situated so close to their host stars that they take only a few days to complete an orbit.

When Mayor and Queloz announced the 51 Pegasi planet, most astronomers assumed it was a freak of nature. Here was a planet that was at least half the mass of Jupiter orbiting its host star in a ridiculously short 4.2 days. At its 5-million-mile distance from the star, a mere one-eighth the Mercury-Sun distance, this planet would be baked to a temperature of about 1000° C. How could such a planet form? How could such a planet survive?

Shortly after the planet's discovery, calculations by Adam Burrows and colleagues at the University of Arizona showed that it was massive enough to hold onto its atmosphere despite its proximity to the stellar inferno. And then in April 1996, Marcy and Butler found a second example of a 51 Peg-type planet orbiting the star Rho¹ Cancri. Within three months Marcy and Butler found two more orbiting the stars Tau Bootis and Upsilon Andromedae. The evidence was undeniable: Roughly 5 percent of solar-type stars have these so-called "hot Jupiters." As Marcy says, "Maybe they think we're weird!"

A year ago, astronomers would have told you that finding four hot Jupiters was about as likely as Madonna taking an oath of celibacy. "We *knew* that you could not generate a giant planet closer in than the asteroid belt," says planet hunter George Gatewood of the University of Pittsburgh.

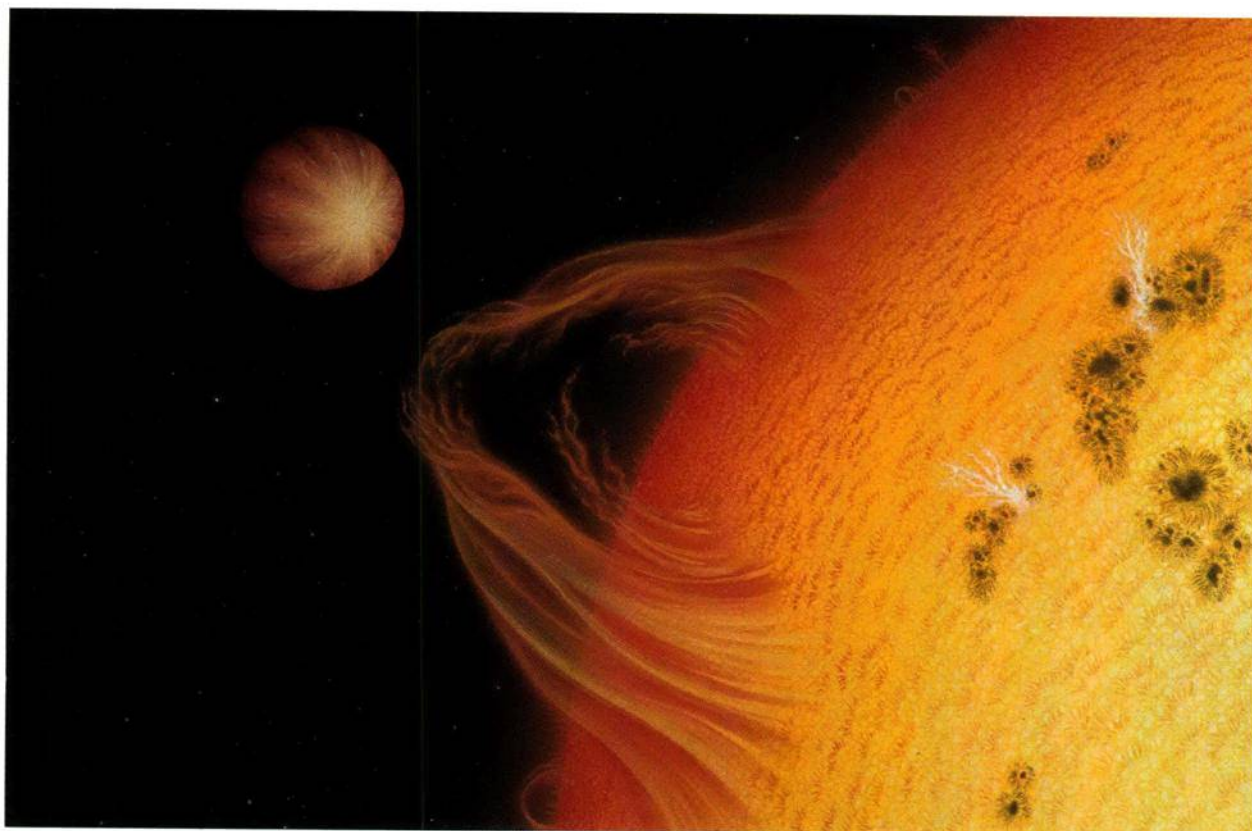
Because nobody has been able to image or take spectra of these hot Jupiters — they were discovered indirectly through their gravitational pull on their host stars — nobody knows exactly what these planets are like. Because there shouldn't be enough rocky material close to a star to form a giant planet, most astronomers think these planets are enormous gas bags similar in composition to Jupiter and Saturn.

According to prevailing theories, a planetary system forms from a disk of gas and dust that surrounds a newborn star. A giant planet forms from a core of mostly ice, with some rock thrown in for good mea-

A freak of nature? Astronomers were stunned to find a Jupiter-mass planet orbiting next door to the solar-type star 51 Pegasi.



"Maybe they think we're weird!"



sure. Once the core attains the mass of several Earths, its gravity gobbles up huge quantities of gas from the surrounding protoplanetary disk. But the young star's intense heat and wind prevents ice from condensing in the inner disk. In addition, the heat and wind drive the gas out of the inner disk, preventing gaseous planets from forming there. Gas giants, so the story goes, can only form in the frigid outer disk, at a distance of at least five times the Earth-Sun distance.

So how does one explain the existence of four Jupiter-mass planets orbiting stars well inside the Mercury-Sun distance? A decade before the hot Jupiters were discovered, planet formation models predicted that under certain conditions, gas giant planets would experience drag forces with their disks that would cause them to spiral inward from their birthplace. But these models had a sad ending: The planets would spiral all the way into the star, like a prisoner walking the plank.

"What 51 Pegasi did was make theorists realize that nature has found a way to save the planets," says Alan Boss of the Carnegie Institution in Washington, D.C., who is himself a planet formation theorist. Doug Lin and Peter Bodenheimer of the University of California at Santa Cruz and Derek Richardson of the Canadian Institute for Theoretical Astrophysics developed a theory to explain how a planet could spiral toward a star without plunging all the way in. According to their scenario, when the planet gets very close to the star, tidal interactions transfer some of the momentum from the young star's rapid spin to the planet's orbital motion. This gives the planet a slight outward boost, thus preventing its death plunge into the star.

This theory works, but it doesn't explain why some

How did they get there? The discovery of Upsilon Andromedae's companion and two other 51 Pegasi-type objects showed that massive planets frequently orbit close to their host stars.

planets march inward, while others, such as those in our own solar system, presumably moved very little from their birthplaces. "My guess is that it has something to do with the lifetime of the disk," says Boss. "Maybe our solar system had a very short-lived disk. In the case of 51 Pegasi, the disk was long-lived, so the system had plenty of time to self-destruct."

While the observations don't rule out the possibility of terrestrial planets in these hot Jupiter systems, they're not likely to be there if the spiral mechanism is correct. First generation terrestrial planets would either spiral all the way to their doom or the giant planet's gravity would eject them from system, taking any chance for life with them. The only hope for life in these systems is if the disk manages to form second generation planets.

Another theory, recently developed by Fred Rasio and Eric Ford of MIT, predicts that if two Jupiter-mass planets form around a star, gravitational interactions will eject one planet from the system while the other will be launched inward toward the star, where it will settle into a tight orbit. This theory is also bad news for life, since any terrestrial planets would be ejected from the system. "A system like our solar system, which has only one dominant massive planet, Jupiter, and is stable over billions of years, may be rare," says Rasio. "The only reason why we happen to live in such a rare system is that long-term stability may be necessary for the development of intelligent life."

The Eccentric Planets

Most planets both inside and outside the solar system, including the hot Jupiters, have orbits that are near-perfect circles. But three of the newly discovered planets have highly elliptical orbits, and thus belong to the family of "eccentric planets."

The first eccentric planet was discovered in 1988 by Harvard University astronomer David Latham's group. The object has a mass of at least 9 Jupiters and orbits the star HD 114762 (remember this name, there will be a quiz at the end of the article). The planet's eccentric orbit brings it as close as a 51-Pegasi-like 0.22 AU to the star and as far as a Mercury-like 0.46 AU (the Earth-Sun distance is 1 AU).

Because the object is much more massive than Jupiter and has such an eccentric orbit, astronomers have been reluctant to classify it as a planet. This explains why Latham was not credited with discovering the first planet orbiting another star.

But if the HD 114762 object isn't a planet, then what is it? For the time being, many astronomers are content to call it a brown dwarf. Brown dwarfs are similar in composition to gas giant planets such as Jupiter. But instead of forming from a disk like planets, brown dwarfs form from collapsing gas clouds, like stars. Brown dwarfs don't shine like stars because they lack the 80 Jupiters' worth of mass necessary to ignite nuclear reactions in their cores. So in a sense, brown dwarfs are transitional objects that bridge the gap in mass between stars and planets.

For eight years, the HD 114762 object was the only example of its type known to science. But in January 1996, Marcy and Butler announced the discovery of a near-twin, an object with a minimum mass of 6.5

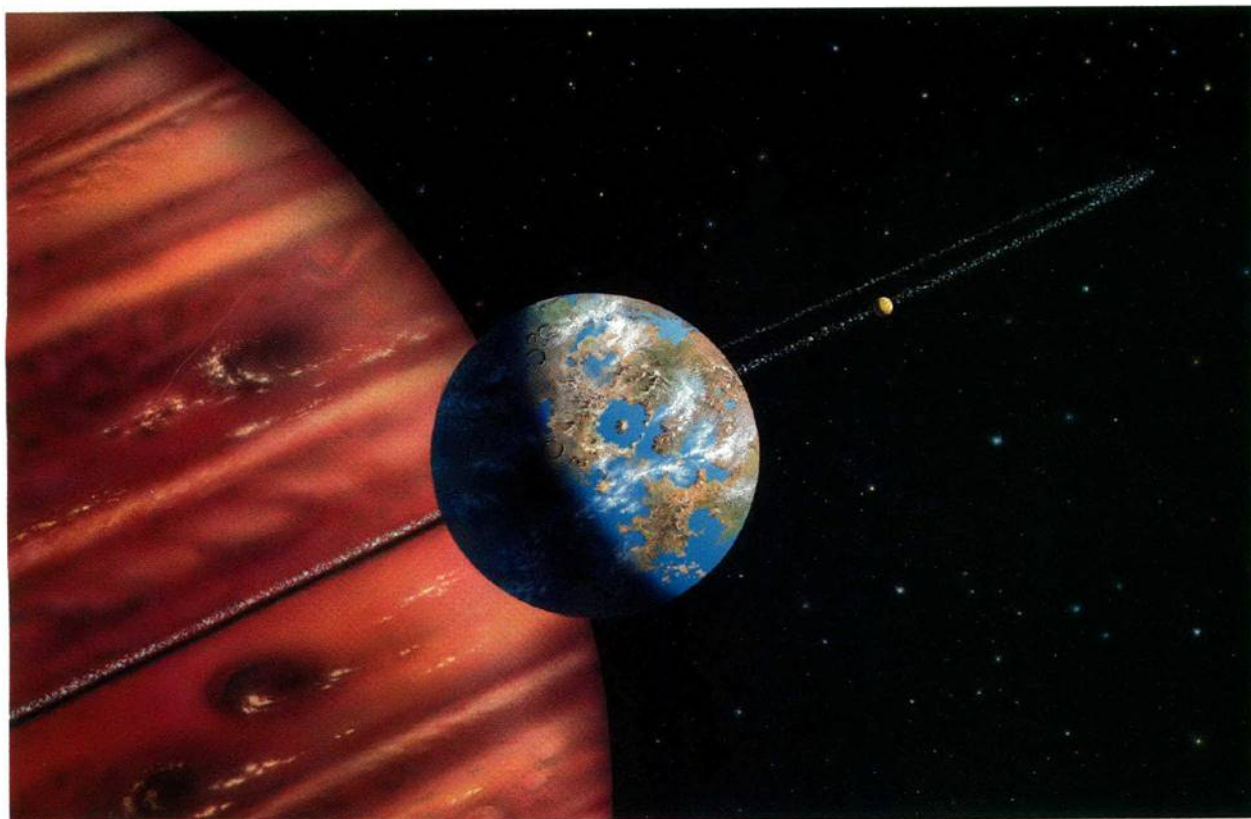
Jupiters orbiting the star 70 Virginis. This object's orbit takes it from 0.27 AU to 0.59 AU, almost the same as HD 114762's companion.

Determining whether these objects are planets or brown dwarfs will be difficult. The mass alone doesn't resolve the issue because there's no theoretical reason why the heaviest planets couldn't be more massive than the lightest brown dwarfs. Even a spectrum — which would reveal the chemical composition of their outer atmospheres — probably wouldn't be enough because both brown dwarfs and gas giant planets are composed primarily of hydrogen and helium.

The critical difference lies deep down in the core. Because a brown dwarf forms from a collapsing gas cloud, like a star, it maintains a gaseous composition all the way to the very center. A planet, on the other hand, forms from accreting material in a disk, and will have a core made of ice and rock. But because we're looking at these objects from enormous distances, it will be virtually impossible to determine their interior structures, which may be the key that will unlock the mystery of how they formed.

Some astronomers argue that eccentricity can tell the tale. Mayor and Queloz have recently discovered 10 brown dwarfs orbiting solar-type stars, and most of them have highly eccentric orbits. Stars in binary systems usually orbit each other in highly eccentric orbits too, so the high eccentricity of the HD 114762 and 70 Virginis objects might be telling us that they formed in the way stars do, making them brown dwarfs.

Planet or brown dwarf? Astronomers are still debating the nature of the massive object orbiting 70 Virginis.



Marcy and Butler counter that the least massive of Mayor and Queloz's 10 new brown dwarfs has a minimum mass of 17 Jupiters, significantly heavier than the HD 114762 and 70 Virginis companions. Marcy and Butler contend that these latter two objects are indeed planets, or that they belong to a separate population. "Maybe they represent a new class that theorists haven't envisioned yet," says Marcy.

Doug Lin and his colleague Shigeru Ida have even developed a model that explains how these objects

"You really can't understand a system when you only have one of them to study."

could have formed from a protoplanetary disk. If two or more massive planets form in circular orbits around a young star, gravitational interactions will stretch out their orbits into ellipses. After tens of thousands of years, the planets will start crossing one another's orbits. Eventually they will collide and merge into a superplanet. Lin and Ida's model yields a single supermassive planet in an eccentric orbit similar to those of the HD 114762 and 70 Virginis companions. The Rasio and Ford model, which is similar to the Lin and Shigeru model, also produces supermassive planets in eccentric orbits. In other words, the hot Jupiters and eccentric planets could be telling astronomers that planet formation can be a much more violent and dynamic process than they had ever imagined.

The Oddball Eccentric

The third eccentric planet is quite different from the other two. Its minimum mass of 1.5 Jupiters is much lower, and it has by far and away the most eccentric orbit of any planet discovered to date. The planet comes as close as 0.6 AU from the star (which would put it inside Venus) and ventures as far away as 2.8

AU (the asteroid belt). "This planet has wild seasonal variation," says co-discoverer William Cochran of the University of Texas at Austin. "But here the seasons are driven by its distance from the star rather than the way our seasons are driven, by the tilt of the axis." Cochran and his colleague Artie Hatzes independently discovered this planet with Marcy and Butler.

The planet orbits 16 Cygni B, a virtual solar twin that belongs to a triple star system. 16 Cygni B and its slightly larger companion, 16 Cygni A, leisurely orbit each other in a cigar-shaped ellipse that takes at least 125,000 years to trace. The third member of the system, 16 Cygni C, is a red dwarf star roughly half the size of the sun that orbits the main pair at a distance of at least 100,000 AU.

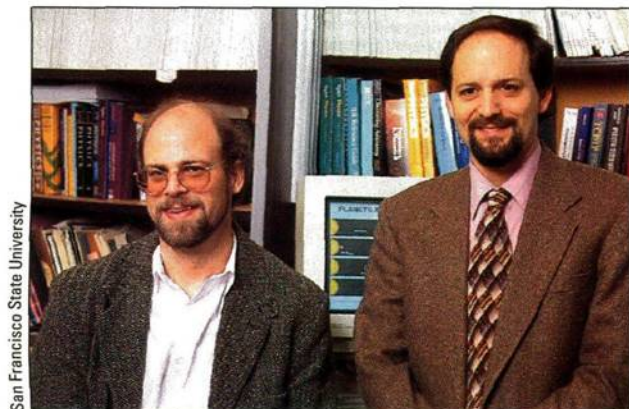
No one knows for sure how this planet ended up with such an eccentric orbit. It could have formed via the colliding planets mechanism suggested by Lin and Ida. Or perhaps when the system formed, gravitational encounters between the three stars stretched the planet's orbit into an ellipse. The simplest explanation is that the planet formed in a circular orbit, but each time 16 Cygni A comes in for a close approach, its gravity tugs on the planet, gradually yanking the orbit into its current elongated shape.

The objects orbiting HD 114762, 70 Virginis, and 16 Cygni B are so massive and have such eccentric orbits that other planets in the stars' "life zones" would either be kicked out of their systems entirely, or would crash into the big planets. If one is prospecting for life, one would be advised to look elsewhere.

The Jupiter-like Planets

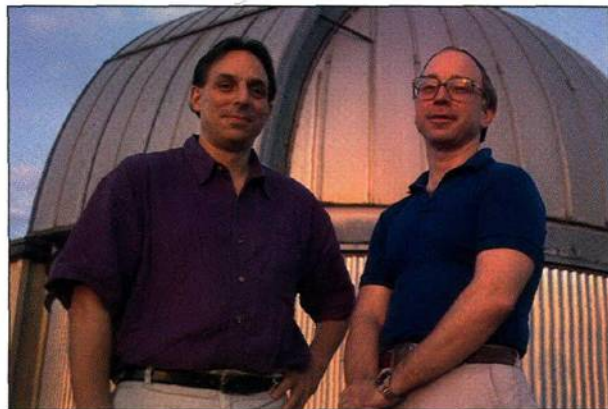
Most astronomers believe that planetary systems like our own, with small, rocky, inner planets and giant, gaseous, outer planets, offer the best prospects for life. But none of the planets discussed so far even remotely resembles the retinue of planets in our solar system. So finding a planet with the same mass and orbit as Jupiter, a true member of the Jupiter family, has become one of the holy grails of extrasolar planet detection. Astronomers have yet to turn up a Jupiter twin, but they have discovered a few planets that sound a note of familiarity.

California-based planet hunters Paul Butler (left) and Geoff Marcy have discovered or co-discovered six extrasolar planets.



San Francisco State University

University of Texas astronomers Artie Hatzes (left) and William Cochran co-discovered the strange planet orbiting 16 Cygni B.



University of Texas at Austin

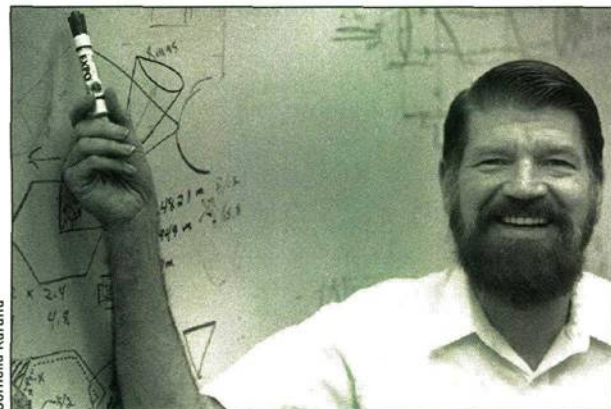
"We're just beginning to get a sense of how bizarre the planetary zoo is."

BIZARRE DENIZENS OF THE PLANETARY ZOO

Star	Spectral Type of Star	Planet Mass (Jupiter=1)	Average Distance from Star (AU)	Orbital Period	Eccentricity	Discoverers
HOT JUPITERS						
51 Pegasi	G3	*0.46	0.05	4.2 days	0.00	Mayor/Queloz
Rho ¹ Cancri	G8	*0.84	0.11	14.7 days	0.05	Marcy/Butler
Tau Bootis	F6	*3.87	0.05	3.3 days	0.02	Marcy/Butler
Upsilon Andromedae	F7	*0.68	0.06	4.6 days	0.11	Marcy/Butler
ECCENTRIC PLANETS						
HD 114762	F9	*9.0	0.34	84.0 days	0.35	Latham, et al.
70 Virginis	G5	*6.5	0.43	116.6 days	0.38	Marcy/Butler
16 Cygni B	G2	*1.5	1.72	2.2 years	0.67	Cochran/Hatzes & Butler/Marcy
JUPITER-LIKE PLANETS						
Jupiter	G2	1.00	5.2	11.9 years	0.05	Prehistory
Saturn	G2	0.30	9.5	29.5 years	0.06	Prehistory
47 Ursae Majoris	G0	*2.3	2.1	3.0 years	0.03	Marcy/Butler
Lalande 21185	M2	~0.9	~2.2	~5.8 years	0	Gatewood
Lalande 21185	M2	~1.1	~11	~30 years	0	Gatewood
UNCONFIRMED PLANETS						
Rho ¹ Cancri	G8	~5	~5	~20 years	?	Marcy/Butler
Upsilon Andromedae	F7	?	?	~2 years	?	Marcy/Butler
Lalande 21185	M2	?	>11	>30 years	?	Gatewood
CM Draconis	M4.5 & M4.5	?	?	?	?	several teams
PULSAR PLANETS						
B1257+12	Pulsar	*0.015 (Earth)	0.19	23 days	0.00	Wolszczan
B1257+12	Pulsar	*3.4 (Earths)	0.36	66 days	0.02	Wolszczan/Frail
B1257+12	Pulsar	*2.8 (Earths)	0.47	95 days	0.3	Wolszczan/Frail
B1620-26	Pulsar	5 to 15 (Jupiters)	~20	~100 years	?	Rasio, et al.

*minimum mass

George Gatewood of the University of Pittsburgh has possibly found a planetary system orbiting the nearby star Lalande 21185.



Cornelia Karaffa

One of Marcy and Butler's first two planets was a world with a mass of at least 2.3 Jupiters orbiting the solar-type star 47 Ursae Majoris. The planet orbits at a distance of 2.1 AU, which would put it on the inner edge of the asteroid belt if it were in our solar system. It's not exactly Jupiter's twin, but it could be a cousin.

Perhaps most intriguing of all, George Gatewood has possibly found two Jupiter-like planets orbiting Lalande 21185, a red dwarf star only 8.25 light-years away — five times closer than the next closest known extrasolar planet. Although each of the dozen or so planets found to date can be considered somewhat uncertain because all of them have been detected through indirect means, Lalande 21185 is the most iffy of them all. Gatewood uses a different technique than the other planet hunters, one that doesn't immediately yield a mass and orbit. He will need to observe the

star for several more years before he can pin down specific masses and orbits. All Gatewood can say for now is that Lalande 21185 appears to be orbited by at least two Jupiter-mass planets at distances of about 2.2 AU (the inner asteroid belt) and 11 AU (a little beyond Saturn) respectively. There are also hints that a third planet orbits much farther out.

Of all the planets found so far, Lalande 21185's purported planets most closely resemble Jupiter in terms of mass and orbit. "I was tremendously reassured

"I'm very happy Columbus has landed so we can get down to the science of the project."

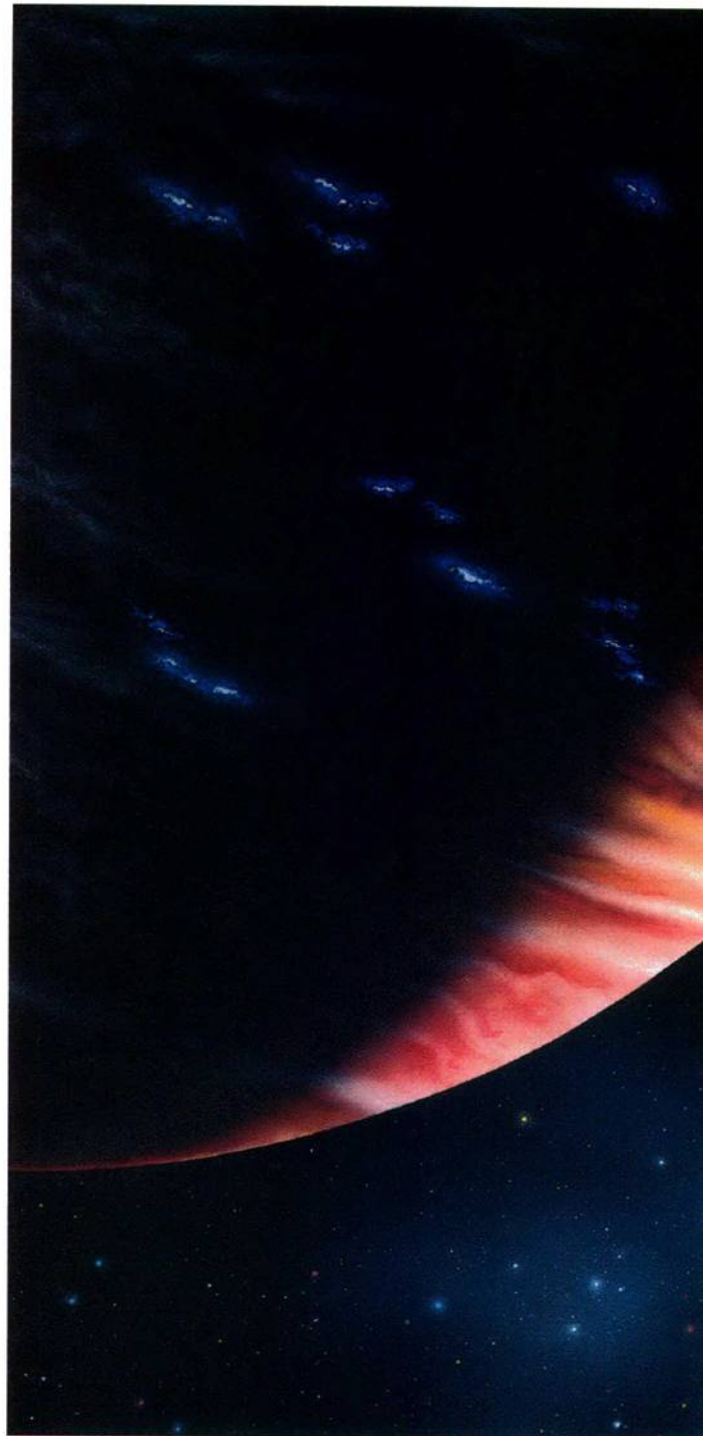
when Gatewood came up with the Lalande 21185 detection because we didn't have anything that looked like Jupiter or Saturn," says Boss. "We might very well have twisted in the wind for quite some time before we found anything that looked like a 'normal' system." Because Lalande 21185 is practically a next-door neighbor, this adds to the excitement as well. If one of the sun's closest neighbors has a similar planetary system, it's not hard to imagine that systems resembling our own are sprinkled throughout the galaxy.

The Next Step

It's been a wacky and wonderful year. In September 1995 astronomers were wondering if Jupiter-mass planets were as rare as gemstones. Now, the number of planets orbiting solar-type stars has jumped from zero (or one, if you consider the HD 114762 object a planet) to a dozen or so. "Things are very encouraging now," says Cochran. "A year ago, everyone in this game was sort of morose. We weren't seeing things, people were trying to explain why this was. Now we're seeing that there's a lot of things out there."

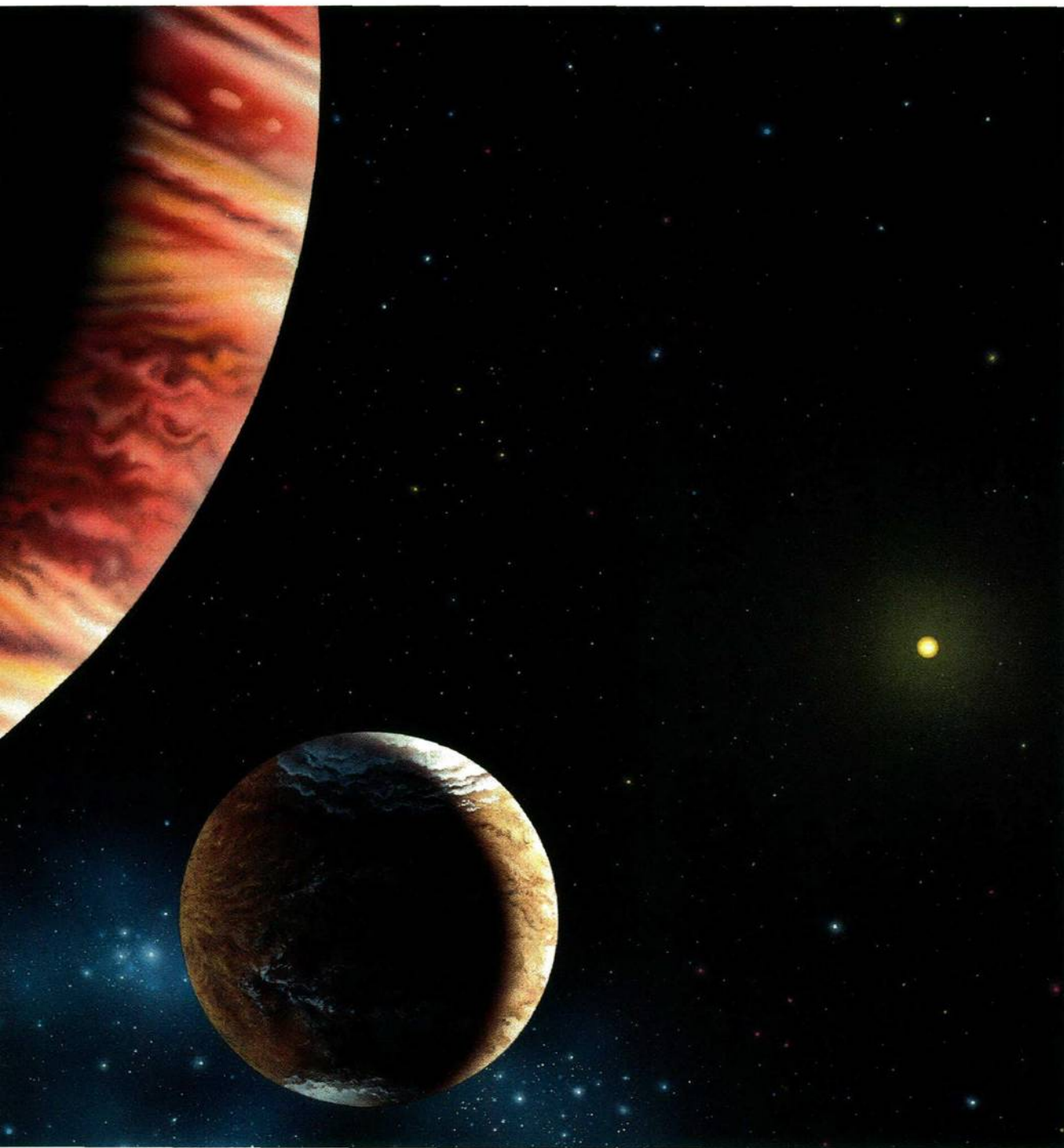
The newly discovered planets have turned theory on its head, demonstrating that planet formation is a much more diverse process than anyone had imagined. Theorists can hardly be blamed for their lack of foresight, however, because until recently they only had one example of a planetary system to study: ours. Because their ideas so beautifully described the architecture of our solar system, it's no wonder they expected to find carbon copies. As Gatewood says, "You really can't understand a system when you only have one of them to study." Now with other systems turning up, and with a diversity exceeding all expectations, the creativity of theorists will be unleashed on the universe.

But before theorists go overboard, one must consider that the searches are most sensitive to massive planets orbiting close to their host stars, which is exactly what astronomers are finding. "The planets we found are the easiest ones to find, and therefore might not be representative of what's out there," says



Cochran. "We have to be very careful about making any broad, sweeping interpretations based on what's been found so far." Butler adds, "We're just beginning to get a sense of how bizarre the planetary zoo is."

To really understand the whole story of planets and planet formation, astronomers need to identify entire systems, like the one that might be orbiting Lalande 21185. Marcy and Butler have compelling evidence for second planets orbiting Rho¹ Cancri and Upsilon Andromedae, demonstrating that astronomers are rapidly making progress in this arena. "We're moving from planet detection to planetary system characterization," says Gatewood. "It's fine to go out and find



new planets, we need to classify these things. But this is all about relating these back to our own solar system. We're going to say, 'Yes, you've found a planet around these stars. See if you can find a second one or a third one.' To say that there's a world here and a world there is more exploration than science. I'm very happy Columbus has landed so we can get down to the science of the project."

With instrumentation and telescopes improving rapidly, and with more teams looking at more stars, the future will be more exciting than the past. Butler offers the following prognostication: "Within the next couple of years, I expect the discovery of systems with

A cousin of Jupiter? The planet and moon orbiting 47 Ursae Majoris wouldn't look too out-of-place in our own solar system.

multiple planets and the discovery of a planet that is as small as 10 Earth masses. We've literally just started scratching the surface, and we're going to find many things that we didn't expect to find." □

Associate editor Robert Naeye (rnaeye@astronomy.com) thinks these new planets are really cool, but his favorite planet is still Earth.

Goodness, Gracious, Great Balls of Fire

A burst of star formation in the nucleus of galaxy M82 gives rise to an immense galactic wind.

What happens when Mother Nature crams huge numbers of newborn stars into a relatively small volume of space? To find out, astronomers need look no further than the nucleus of M82, an irregular disk galaxy located some 10 million light-years away in Ursa Major.

M82 is the classic example of a starburst galaxy, each year its nucleus alone converts 10 suns worth of gas into stars. The much larger Milky Way Galaxy is downright quiescent in comparison, forming perhaps five solar-masses of stars per year in the entire galaxy.

Astronomers believe the roots of M82's starburst date back some 100 million years, when the hapless galaxy experienced a close encounter with the massive companion spiral galaxy M81. The gravitational interaction jostled M82's gas clouds, igniting the starburst.

Many of M82's newborn stars are of the supermassive variety. These stellar brutes quickly exhaust their nuclear fuel and explode as supernovae, adding to the cosmic fireworks display. As recently as a few million years ago, 30 supernovae were going off in M82's nucleus each century. Because the starburst appears to be waning, the rate has slowed to five per century, which is slightly higher than the rate in the entire Milky Way. That's a lot of pop for a galaxy that has only one-tenth the mass of the Milky Way.

M82's massive young stars and supernovae give off furious winds of hot

gas, which combine to form an even more powerful galactic wind. Because the starburst region is surrounded by a disk of dense gas that is aligned with the plane of the galaxy, the galactic wind escapes above and below the galactic plane, creating the filamentary structures seen in the photo on the facing page.

This 50-minute exposure was taken through a filter that captures emission from hydrogen gas heated to 10,000 kelvins (18,000° F), which is hot enough to ionize the gas. Patrick Shopbell of Caltech and Jonathan Bland-Hawthorn of the Anglo-Australian Observatory used this image, along with other data, to measure the speed and direction of M82's galactic wind. The wind stays confined to a cylinder within 1,100 light-years of the disk. But the wind subsequently fans out at a speed of 1.3 million miles per hour, forming cone-shaped structures. Recent computer models of galactic winds predict similar shapes and velocities.

"In the distant past, galactic mergers and encounters were more common," says Shopbell. "Starbursts in some galaxies played a more important role than standard star formation mechanisms. This tells us a lot about how galaxies evolved over time." —Robert Naeye

A powerful galactic wind streams away from the nucleus of M82, a galaxy that's experiencing a burst of star formation. The wind regions are the filamentary structures extending vertically for tens of thousands of light-years from M82's core. R. Brent Tully took this image with the University of Hawaii's 88-inch telescope that sits atop Mauna Kea.



When Neutron Stars Collide

Forget about marauding asteroids — merging binary stars could wipe out all life within 3,000 light-years.

by Robert Zimmerman

Two stars are about to die. For billions of years they have orbited each other, a pair of massive fiery orbs molded and shaped by the exchange of matter and energy between them. After the first few million years, the heavier star had exploded as a supernova, becoming a tiny, compressed neutron star with its giant companion still orbiting about it. Later, this second star also erupted as a supernova, leaving two pulsars whirling about each other for untold millions of years.

With each blinding orbit, mere minutes long, their combined mass of roughly three suns would cause a ripple in the fabric of space. These concentric waves of gravity would roll outward from the binary, carrying with them the system's orbital energy. Over the eons, the stars inexorably crept closer together, spiraling inward for what would soon become a final, cataclysmic embrace.

Now they are less than 500 miles apart, and their orbital decay begins accelerating. In less than 15 minutes their period of revolution dwindles to less than a thousandth of a second, their speed accelerates to more than a third the speed of light, and their separation melts to practically nothing. When they are about 20 miles apart, the two pulsars begin ripping mass from each

other while also tearing their interiors apart. Then, in an almost instantaneous flash, they smash against each other, swiftly coalescing into a single black hole and releasing more energy than all the other stars in the entire universe.

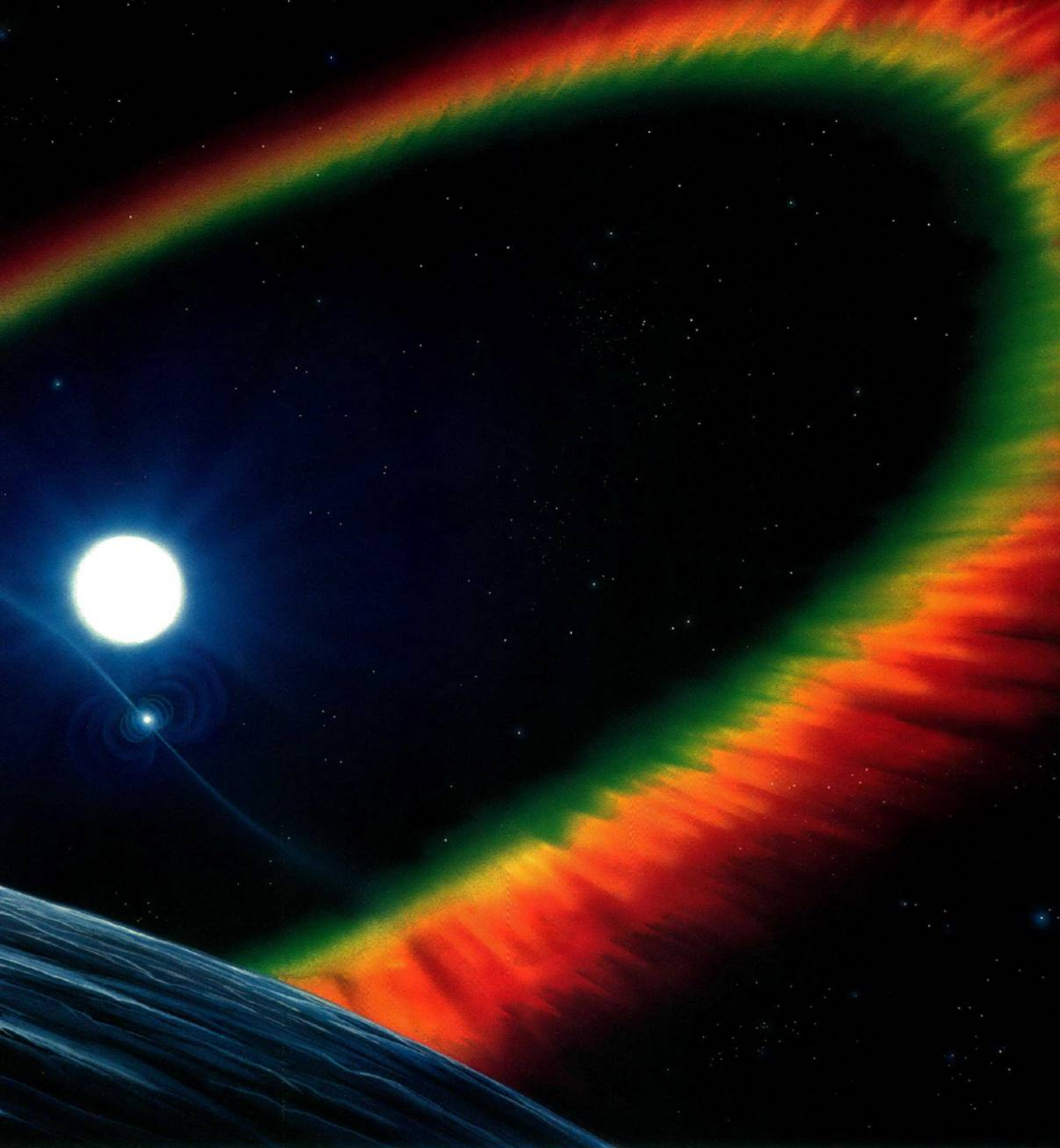
It is this event, or others like it, that more and more astronomers are beginning to believe causes the mysterious gamma-ray bursts that have baffled researchers for more than 25 years. More significantly, if this conclusion holds, it will mean that such events could take place not only within our own galaxy but also close enough and often enough to influence events on Earth. A merger of two neutron stars as far away as 3,000 light-years could conceivably wipe out life on Earth.

This growing consensus started to develop after the launch of the Compton Gamma-Ray Observatory in 1991. Gamma-ray bursts can last anywhere from a few thousandths of a second to several minutes and vary rapidly in intensity over that time period. These observational facts have led astronomers to think they are caused by relatively small objects, certainly less than 50 miles across.

Prior to Compton, most astronomers assumed that such diminutive objects could not release the energy necessary to be seen from

outside our galaxy. Instead they believed the bursts were taking place on nearby neutron stars: possibly a neutron star experiencing a starquake or a large object crashing onto its surface. Regardless, they expected Compton to find that the distribution of bursts across

Paul DiMare



the sky would mimic the distribution of all objects in the Milky Way Galaxy, centering along its plane.

Expanding Fireballs

A few scientists disagreed. In 1986, before Compton's launch, astrophysicist Bohdan Paczynski

of Princeton University proposed that gamma-ray bursts could be taking place outside our galaxy, even though this vastly greater distance would require the bursts to release much more energy, equivalent to roughly 100 billion billion suns and greater than all

High-energy beams of radiation escape from the magnetic poles of a pulsar just as its massive companion star explodes. If the binary system survives the supernova, the two neutron stars left will eventually spiral into one another, perhaps triggering a deadly gamma-ray burst.

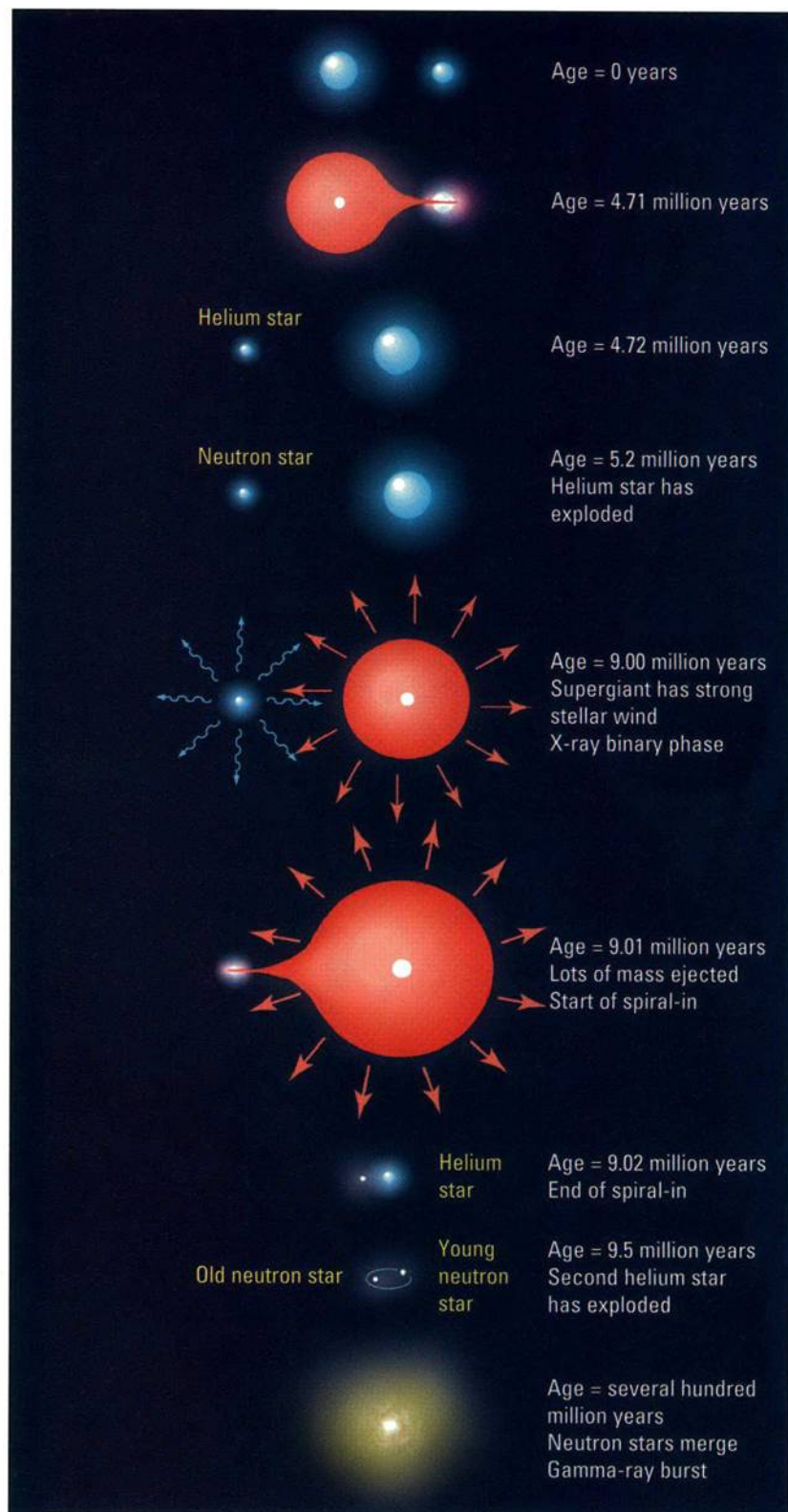
that produced by the rest of the universe for that instant of time. He suggested colliding neutron stars as a possible cause and noted that such smash-ups would release about the right amount of energy.

Then the Compton Observatory was launched and, to the chagrin of most other astronomers, found that gamma-ray bursts were not confined to the galactic plane but appeared across the whole sky. The bursts had to be arising either within a very large halo around our galaxy or across the full span of the universe. And while some astronomers still hold with the galactic halo theory, in the last few years the constraints have become so tight that most scientists have accepted that gamma-ray bursts occur throughout the universe.

Suddenly, Paczynski's idea of neutron star mergers seemed more appealing. Others chimed in with their own theories, including the capture or disruption of a neutron star by a black hole, or the sudden collapse of a white dwarf into a neutron star as it accreted matter. Only these catastrophic events seemed capable of releasing the vast amount of energy needed in the required small volume.

Not surprisingly, theoretical problems still exist. Although neutron star collisions release enough energy, they apparently do not do so in the form of gamma rays. Instead, they produce neutrinos and gravitational waves, as well as eject matter at very high speeds. The neutrinos, as they are wont to do, pass through the universe with little notice. The gravitational waves, while enormously powerful, merely roll across space like waves on a beach: floating objects only rise and fall as the waves sweep past. And the ejected matter, while flying outward at almost the speed of light, merely creates a front of ionized matter before it.

Furthermore, no two gamma-ray bursts seem alike. Unlike supernovae, gamma-ray bursts follow no set pattern. Sometimes they rise slowly to a maximum, other times fast, and often their emission consists of many random jagged peaks. Some bursts last mere milliseconds, others can go on for minutes.



ASTRONOMY: Lee Vande Visse, after E.P.J. van den Heuvel

Gamma-ray bursts may arise when two neutron stars merge. Imagine a binary system containing two massive stars. The more massive one evolves quickly into a red supergiant whose outer layers flow onto the smaller star. The exposed core, a helium star, soon explodes as a supernova and leaves behind a neutron star.

With the added mass, the other star soon evolves into a supergiant. Eventually its atmosphere spills onto the neutron star, which spirals in due to friction. The supergiant, now a helium star, then explodes, leaving behind two neutron stars. Radiating gravitational waves, the stars spiral in and then merge in a burst of gamma rays.

Despite these difficulties, many astronomers have tried to squeeze gamma rays from these collisions. Their quest has been bolstered by the all-too-coincidental realization that such stellar calamities are thought to occur at almost the same rate as gamma-ray bursts are observed, around 900 per year within the observable universe.

The result has been a myriad of theories and models, all of which require a variety of assumptions in order to work. For example, Mario Vietri of the Astronomical Observatory of Rome proposed recently that gamma-ray bursts could take place just before the neutron stars merge. Assuming that such a system has a powerful magnetic field, the motion of the pulsars through that field could produce the wide range of known bursts.

Radiation Snowplow

Conversely, Nir J. Shaviv and Arnon Dar of the Israel Institute of Technology have suggested that gamma-ray bursts could take place just after the neutron stars merge. Assuming that such mergers take place inside the dense stellar regions of galactic nuclei or globular clusters, Shaviv and Dar contend that atoms in the cloud of matter ejected at almost the speed of light will collide with and then absorb part of the intense starlight that surrounds them. This "radiation snowplow" will gather up that starlight and beam it forward in the direction of the ejected matter's motion. The beamed light is then Doppler-shifted to gamma-ray energy, finally producing the short bursts we see from Earth.

In a similar variation, Peter Meszaros of Pennsylvania State University and Martin Rees of the Institute of Astronomy in Cambridge, England, have suggested that when a black hole eats a neutron star, it is left for a short while (mere seconds) with a surrounding torus of debris as well as jets of material shooting outward from its north and south magnetic poles. Because the jets spurt unevenly, they produce an assorted series of expanding shells, with each shell moving at close to the speed of

light, albeit at slightly different velocities. As the faster shells catch up with the slower shells, they collide, and it is this random interplay that produces the wide range of burst signals seen from Earth.

Not surprisingly, none of these models, along with the hundred or so other theoretical proposals presently in print, satisfy every question. "All are plausible, but there is no way to prove any of them," says Paczynski.

Despite the lingering doubts of some astronomers, many others

Colliding neutron stars will eject a cloud of matter at almost the speed of light.

seem ready to accept neutron star collisions as the most likely cause of gamma-ray bursts. "At the moment they offer us the best known scenario," says Paczynski.

The Consequences for Earth

Provocatively, this growing consensus presents us with a new and unexpected threat to life. In 1995 Stephen Thorsett of Princeton University tried to estimate the danger of such neutron star mergers on Earth and concluded that a merger closer than about 1,500 light-years could do significant harm. According to Thorsett, "the merger of a binary system this close to Earth would bathe our planet with approximately 10,000 megatons of TNT, roughly equal to the total worldwide nuclear arsenal." Such an explosion would destroy the ozone layer, make both the atmosphere and Earth's surface radioactive, and produce large climatic changes.

More recently, Dar, Shaviv, and Ari Laor did a similar study and estimated that any such calamity within 3,000 light-years of Earth could make all life extinct. Because the best estimates predict mergers in our galaxy roughly three times every 100,000 to one million years, they say that "in Milky Way-like galaxies, such explosions would destroy advanced life on every nearby Earth-like planet on the average every 100 million years."

What makes these binaries especially intriguing is that their eventual merger is predictable. Just as astronomers can precisely calculate the occurrence of a solar eclipse, they can predict with reasonable accuracy the moment when these binaries will collide, bathing nearby space with their deadly gamma radiation.

Astronomers estimate that about 240 neutron star binary systems exist within the plane of our galaxy and already have firmly identified three. Of these, two are heading toward merger. The binary system PSR B1913+16 will coalesce in about 410 million years and PSR B1534+12 will do so in 2.73 billion years. This second system lies less than 1,500 light-years away and could, according to Dar, "have noticeable effects on Earth" when it merges.

The irony is exquisite. For more than a quarter century, gamma-ray bursts have baffled the astronomical community. In their effort to explain these enigmatic eruptions, scientists have been forced to shift their theorized location farther and farther from Earth, until today we believe them to explode in the outermost reaches of the universe.

Yet this shift away from Earth has only brought gamma-ray bursts closer to home. Like time bombs, we have found that they might be hidden nearby, ticking inexorably toward explosion.

As we improve the map of our galactic home, we will likely locate more of these strange binary systems, and calculate when they will explode. We will also map with better accuracy our own sun's path through the galaxy, laying out precisely where we will be when such explosions occur.

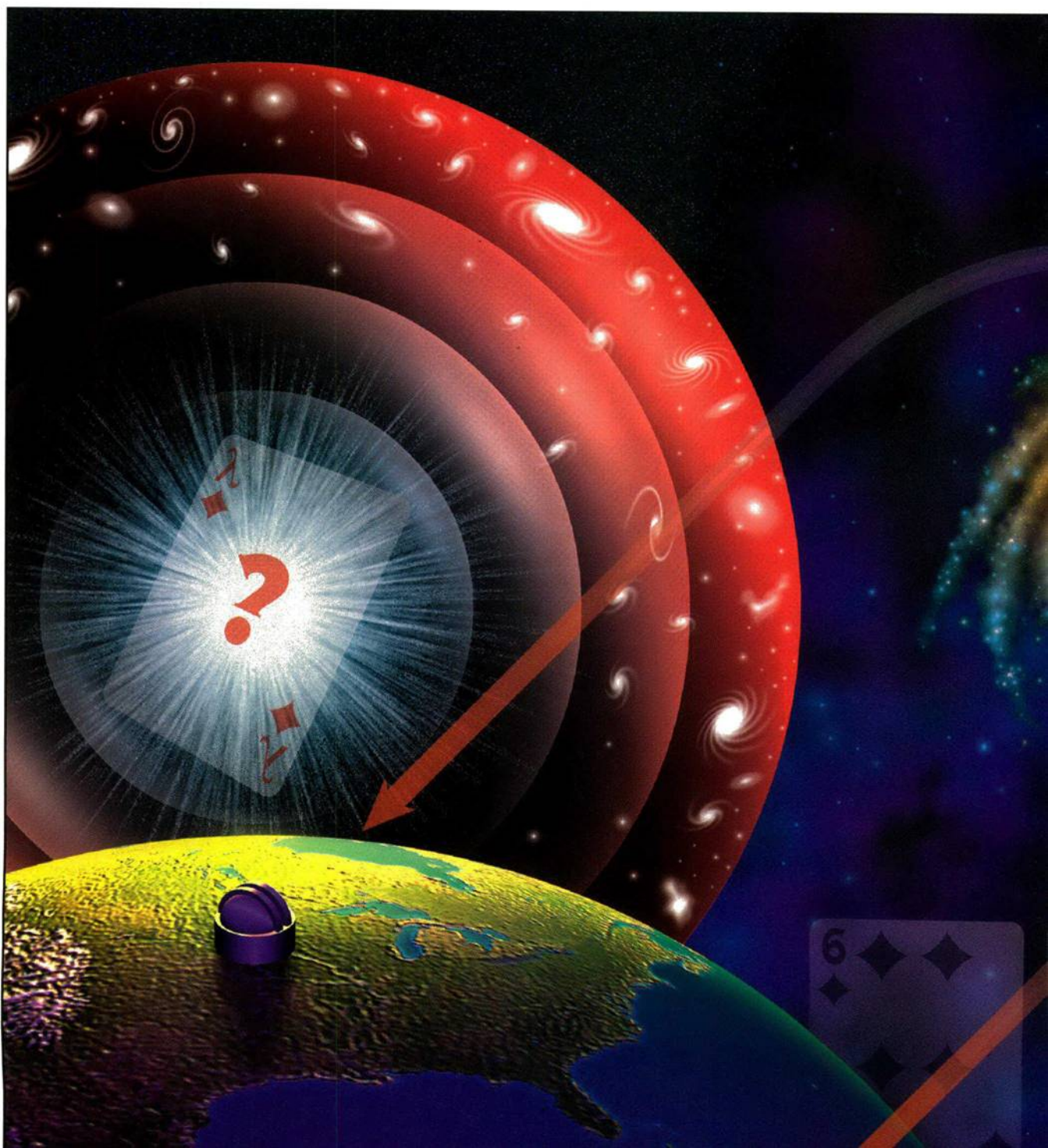
When we have done this work, we will have ample warning of any future threat. What we will do then, however, is a question that no one at this time can answer. □

Robert Zimmerman is a filmmaker, writer, and cave explorer who writes often on science, astronomy, and space exploration. Although he knows humanity will soon conquer space, he wonders why it is taking so long.

Wild Card

Einstein disowned it, no one likes it, but astronomers may need the cosmological constant to reconcile the universe with its oldest stars.

by Ken Croswell



The game started well. Your hand looked good, with lots of face cards, and you bet plenty of money on the outcome. But now the game has turned against you; you've played all your kings and aces, and you're losing badly. In desperation, you reach for the wild card in the deck, the card that just may salvage the entire gamble.

Today, astronomers playing the high-stakes game of cosmology find themselves in a similar predicament, one that threatens the very foundation of modern cosmology: the big bang theory. Recent measurements suggest the universe is expanding so fast that it had zero size just 9 to 12 billion years ago. But the Galaxy's oldest stars are thought to be 15 bil-

lion years old — older than the universe. "It's a serious problem to have stars in the universe that are older than the universe itself," says Princeton cosmologist Edwin Turner. "That tells us that something is wrong."

Enter, then, the wild card in the deck of modern cosmology: the cosmological constant. "With the cosmological constant, you can put together a model where the universe actually began expanding 15 or 16 billion years ago and therefore accommodates the oldest stars," says Turner. The cosmological constant represents the repulsive force of empty space. A universe with such a repulsive force expanded more slowly in the past and so is older than a universe without this force.

Still, no one likes the cosmological constant, in part because its numerical value, like that of a true wild card, seems arbitrary, a fudge factor invoked to save big bang cosmology. In 1990, though, astronomers discovered a powerful technique for actually measuring the cosmological constant's value, and they soon hope to prove once and for all whether it can rescue them from their worst crisis.

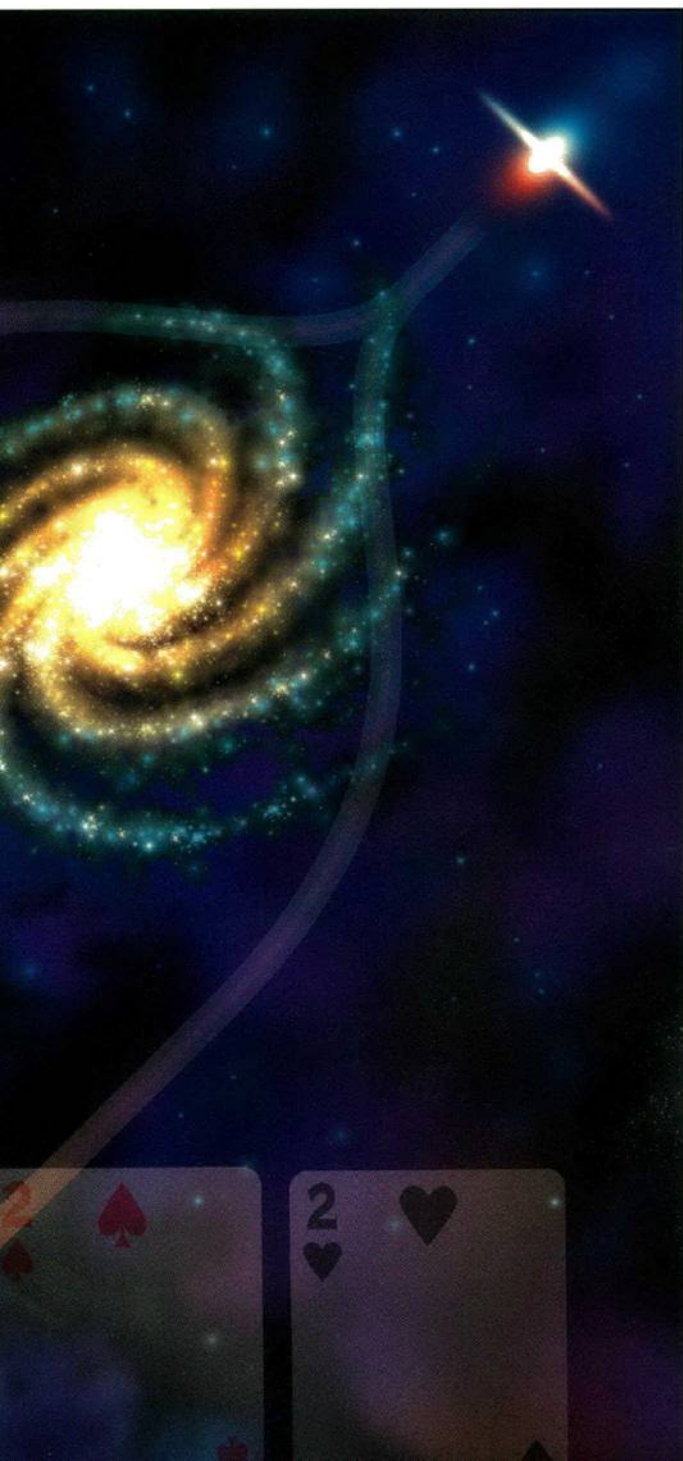
A Timely Problem

To see how the cosmological constant increases the age of the universe, recall that the present rate of the universe's expansion, the so-called Hubble constant, indicates the universe's age. The larger the Hubble constant, the younger the universe, because a fast-expanding universe has taken less time to reach its present size.

Recent measurements suggest that the Hubble constant is around 75 kilometers per second per megaparsec, which is higher than most cosmologists would like. For example, the 1994 detection of Cepheid variable stars in the Virgo Cluster gave a value for the Hubble constant of 80, and the 1995 discovery of Cepheids in the Fornax Cluster led to a Hubble constant of 73. If the Hubble constant is 73, then the universe would be only 9 to 12 billion years old, which is clearly a losing hand at the cosmological casino.

The amount of mass in the universe also influences the age of the universe. Cosmologists express the mass density of the universe using the final letter of the Greek alphabet, omega (Ω), since omega determines the final destiny of the universe. If omega is less than 1, there is too little mass to stop the expansion, and the universe will keep expanding forever. On the other hand, if omega is greater than 1, the universe is so massive that it will eventually collapse in a Big Crunch.

Both observation and theory suggest omega is somewhere in the broad range between 0.1 and 1.0, which means that the universe will expand forever. The greater omega is, the younger the universe must be. That's because mass has gravity which slows the universe's expansion, so the more massive the universe is, the faster it expanded in the past. If the universe's expansion was faster in the past, it didn't take as long to reach its present size. For example, if omega is 0.1 and the Hubble constant is 73, the universe's age is 12.0 billion years. But if omega is 1.0, the universe is a mere 8.9 billion years old, barely half the age of the oldest stars — if there is no cosmological constant.



George Krauter

Play the Wild Card

A cosmological constant can save the entire game because it boosts the age of the universe. The cosmological constant represents a sort of antigravity force that acts in the opposite manner as omega. Whereas omega slows the universe's expansion, the cosmological constant speeds it up. If the cosmological constant exists, the universe expanded more slowly in the past, so the universe can be older than the oldest stars even if the Hubble constant is as high as 80 or even 90.

The cosmological constant represents the energy of completely empty space. Intuitively, it seems that empty space should have zero energy and, if so, the cosmological constant is zero. But if empty space does have energy, that energy can act as a repulsive force, which grows as the universe gets larger, since a large universe has more empty space than a small one. Therefore, the expansion of a universe with a cosmological constant accelerates, like a runaway train.

In fact, it was just this repulsive property that led Albert Einstein to introduce the cosmological constant into his equations of general relativity. In 1917, when Einstein applied his equations to the universe, he found that the weight of the universe made it collapse. To hold up the universe, he invented the cosmological constant, whose repulsive force exactly balanced the attractive pull of the universe's mass, giving Einstein what he wanted, a static universe.

In the late 1920s, however, Edwin Hubble discovered that the universe is expanding. Einstein threw out the cosmological constant, calling it the biggest blunder of his scientific life. "That expresses the feeling people have about it," says Turner. "It just doesn't have theoretical elegance or beauty; it doesn't make much sense." After all, it means *empty* space

The cosmological constant acts like an antigravity force, causing the universe to expand faster and faster over time.

exerts power over the universe's ultimate destiny.

Yet if the cosmological constant exists, it can readily resolve the age conflict between the universe and its oldest stars. Cosmologists represent the cosmological constant with the Greek letter lambda (λ). If the cosmological constant does not exist, then lambda is 0. If the cosmological constant does exist, its repulsive energy counteracts the gravitational attraction of the universe's mass and tries to accelerate the expansion.

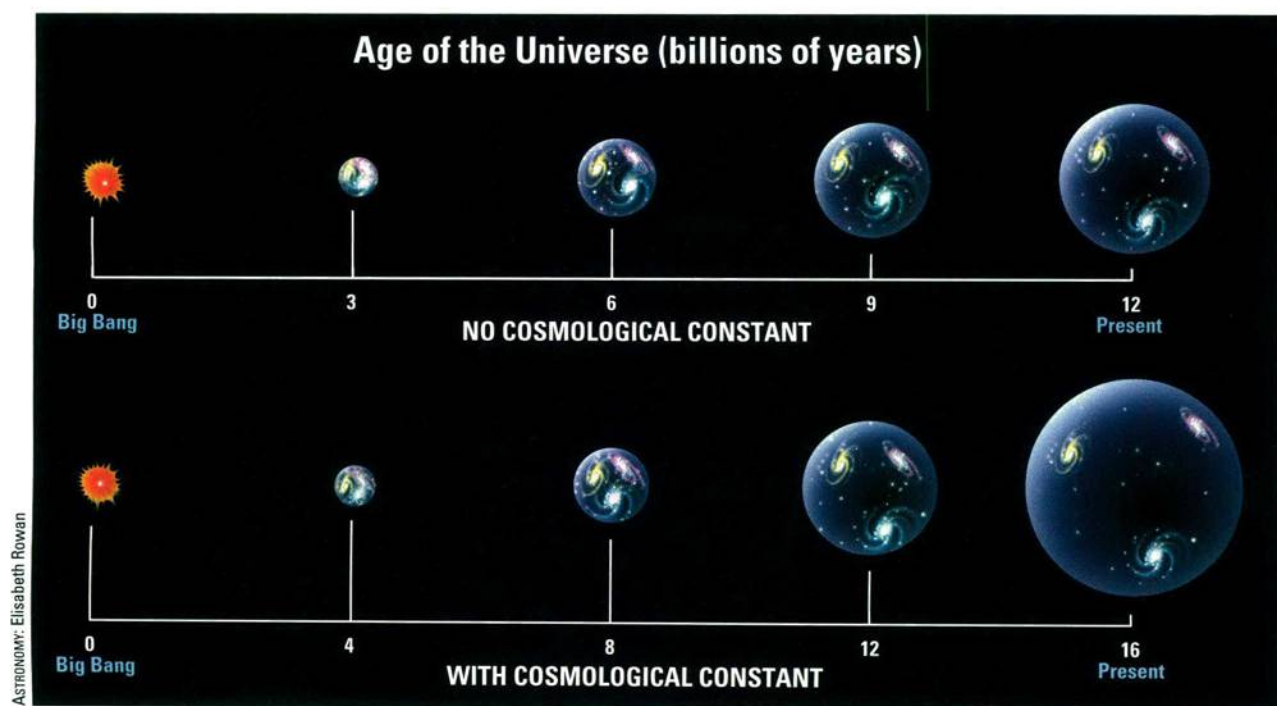
The larger the cosmological constant is, the older the universe is. For example, if the Hubble constant is 80, omega is 0.1, and the cosmological constant is 0, the universe is only 11.0 billion years old. But if the cosmological constant is instead 0.9, one can calculate that the universe is a more mature 15.6 billion years old.

Zeroing in on Lambda

Of course, it's just this great freedom that causes scientists to distrust the cosmological constant, for like a wild card its numerical value seems to be anything the player wants. Actually, though, the cosmological constant's numerical value is not arbitrary; astronomers can attempt to measure its value, just as they can the Hubble constant and omega.

But doing so is not a simple task. "It's very difficult to measure," says Turner, "because it has effects only on very large scales. It's a force that becomes bigger and stronger as the universe expands; it's a force that grows with distance. So we have to look out to large distances."

In 1990, however, Turner and a team of Japanese astronomers independently discovered a powerful new technique to measure the cosmological constant's numerical value. This technique involves gravitational lensing, in which a massive galaxy — usually a giant elliptical — sits between Earth and a distant quasar and splits the quasar's light into two or more beams.



The larger the cosmological constant, the more gravitationally lensed quasars there should be. The reason, in part, is that the larger the cosmological constant, the farther away is a quasar with a particular redshift. This increases the chance that a giant elliptical galaxy lies between the quasar and us that can lens the quasar's light.

This is no small effect. "The number of expected lenses rises very steeply as λ approaches 1.0," says Christopher Kochanek of the Harvard-Smithsonian Center for Astrophysics, who has tried to convert present observations of gravitationally lensed quasars into constraints on the cosmological constant. "A λ of 0.1 or 0.2 doesn't do very much. It's when you reach λ of 0.8 to 1.0 that the lensing probability shoots up very rapidly."

Since 1990, however, searches for gravitationally lensed quasars have turned up relatively few examples, suggesting that the cosmological constant is small. Only about 1 percent of quasars are lensed, whereas a universe with a large cosmological constant — λ around 0.8 or 1.0 — would have five to ten times as many gravitational lenses.

"If λ was 0.8," says Kochanek, "you would barely have to open the dome of the telescope to find a gravitational lens. We'd have lenses coming out of our ears. In that sense, it's almost a pity that λ isn't high." Kochanek says that the latest data indicate that λ is probably less than 0.6, which helps with the age crisis, but not enough to solve it completely.

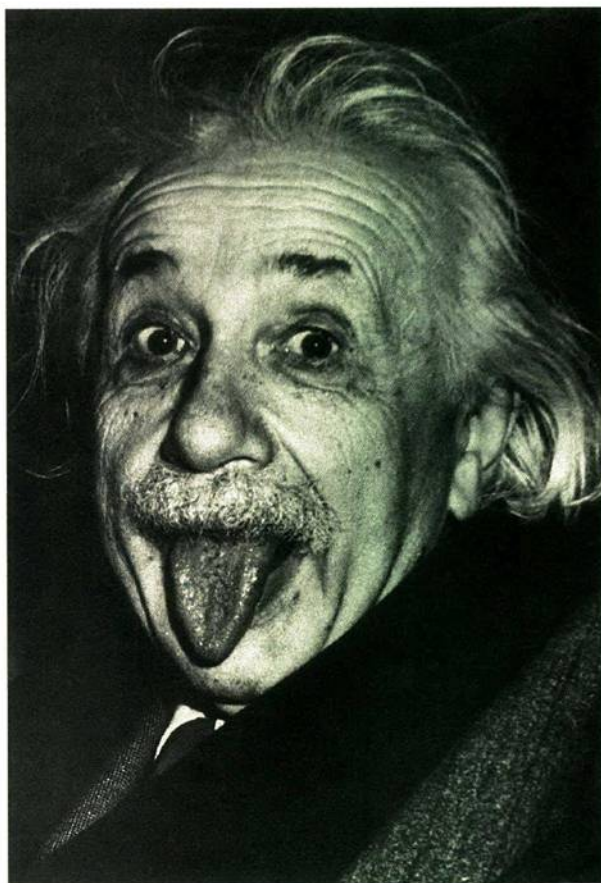
Kochanek even doubts that the cosmological constant exists at all. "I'd bet your life there isn't one. Notice I said your life, not my life. You do the best job you can on the calculation. But you can't include every conceivable systematic error. So realistically, you'd be foolish to rule out the possibility that one of the assumptions in the lensing calculation is wrong." For example, the giant elliptical galaxies that lens quasars may once have been so dusty that they hide the quasars completely from our view.

Turner shares Kochanek's assessment. "My inclination is to think there isn't a cosmological constant," says Turner. "The best fit to the lens statistics is with a very small or zero value, and I'm as influenced as other people by the aesthetic arguments. So my intuition is that it's probably zero and that the solution to the age crisis probably lies elsewhere. But these measurements are difficult, and I wouldn't claim that they have completely ruled out large values of λ . I'd bet you ten dollars that λ is 0, but I don't think I'd bet my house on it."

A Constant Problem

Both Turner and Kochanek expect rapid advances in measuring the cosmological constant over the next ten years — advances that will finally put an actual number on what is now little more than cosmology's wild card.

"In ten years," says Turner, "there's a good chance that we will know whether or not the cosmological constant is zero, because gravitational lens surveys are improving rapidly." In addition, he expects improved measurements of the Hubble constant and stellar ages,



Even though Einstein coined the term, the cosmological constant left a bad taste in his mouth.

but he says those might possibly make the age crisis even worse. "I can imagine that happening in the next ten years," he says. "To really have a convincing measurement of the Hubble constant and a convincing measurement of the stellar ages, and to find that the stars are older than the expansion age of the universe — that would be the way that we could find out if the cosmological constant was really there."

But in the high stakes world of cosmology, the game isn't over till it's over. Most hope that new observations will yield slightly lower values of the Hubble constant and slightly younger ages of the oldest stars. Then astronomers will just barely squeak out of the age problem and not have to resort to playing their wild card.

However, it's also possible that the opposite scenario will unfold: The Hubble constant will remain high and the oldest stars far too old for comfort. Then big bang cosmologists will have no choice but to play their trump card, the cosmological constant. And if that turns out to be a deuce rather than an ace, cosmologists will have just one more thing left to do: dump the big bang and deal another round. □

Ken Croswell is author of The Alchemy of the Heavens and Planet Quest, an upcoming book about the discovery of the first extrasolar planets. The home page for both books is <http://www.ccnnet.com/~galaxy/>.

Tell Time by the Big Dipper

Who needs a watch when the sky tells us what time it is on every clear night?

by Gary Grittner

It's late at night and you're doing some observing. You've forgotten your watch. It sure would be nice to know what time it is. Well, since it's clear, why not use the Big Dipper as a clock? Using it to tell time is easy. All you need to know is the day of the year and the position of some stars around the North Star. With practice, you can gauge time to within 30 minutes.

The principle behind this celestial clock is simple. Because Earth rotates once every 24 hours, stars appear to move from east to west and return to their original position in about 24 hours. The celestial pole, a point directly above Earth's north pole, appears to stand still throughout the night while all the other stars make circles around it.

Fortunately, Polaris the North Star is very close to the celestial pole, so it can serve as the center of our imaginary celestial clock. To find it, look overhead for the

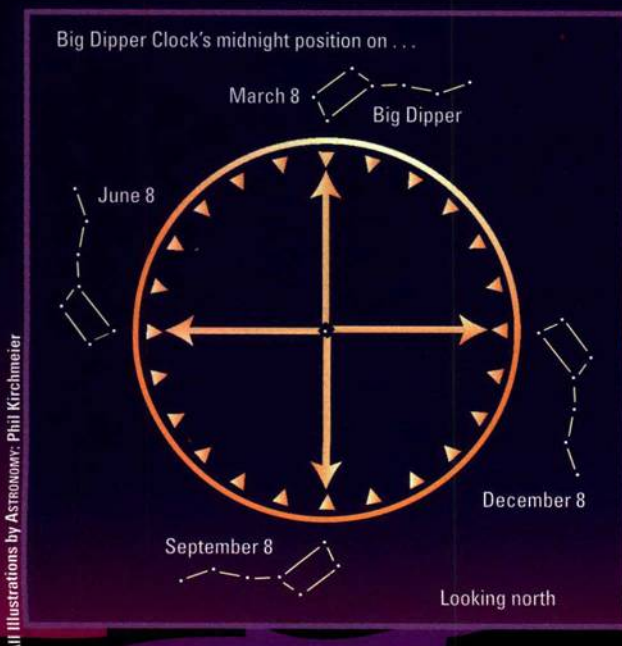
Big Dipper in Ursa Major. Two stars on the end of the Dipper's Bowl, Dubhe (Alpha [α] Ursae Majoris) and Merak (Beta [β] Ursae Majoris), point a line to Polaris. This line doubles as the hour hand of our clock.

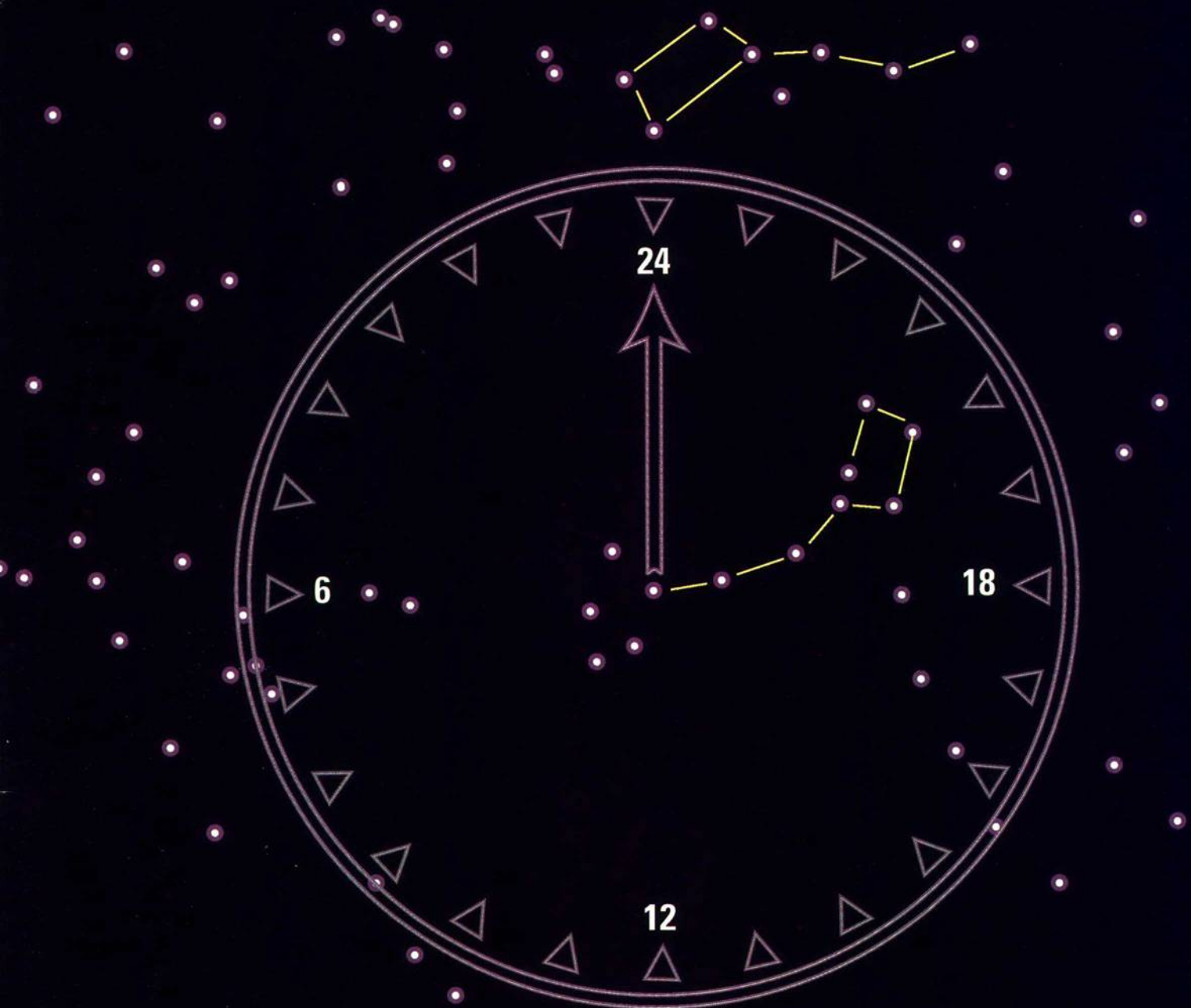
There are differences between normal clocks and the celestial clock. Our star clock has a 24-hour face. It also runs fast — 24 hours fast each year — so you'll make a few adjustments to get the correct time. Finally, the celestial clock runs backwards.

Once you account for these differences, telling time is not difficult. First, compensate for the clock running fast. This is caused by Earth revolving around the sun every 365 days. Because a complete circle consists of 360 degrees, our planet advances about 1° per day in its orbit.

This makes the hour hand move counterclockwise, or fast, about 1° per day on the clock's circular face. One week's worth of "fast running" translates into half an hour on the clock face. After one month, the celestial clock is two hours fast.

Our celestial clock only lines up with the real time at midnight on March 8. This is when the clock's hour hand, the line that connects the Big Dipper's pointer stars to Polaris, lies directly overhead at midnight.





Because of this, the midnight hour of March 8 will serve as our calibration time for the rest of the year. At that moment the hour hand points due south through the zenith. Its position defines 24 hours, or midnight, on the celestial clock face. Fill in the rest of the face by placing 18:00 (6 p.m.) immediately to the right of Polaris, 12:00 (noon) straight down to the northern horizon, and 6:00 (6 a.m.) to the left.

Now all the elements are in place to use our celestial clock over the coming months. First, recreate in your mind the clock face's orientation as defined

in March. Remember that the line that runs from Polaris through the zenith defines the clock's midnight, 24:00 position.

To read the celestial clock's current time, note the hour hand's position and then calculate the "fast running" correction factor, working forward from March 8. Subtract two hours for each month after that date, 30 minutes per remaining week, and 4 minutes per remaining day. Finally, add an hour for daylight savings time, when appropriate. Your answer is the local time, accurate to 30 minutes, as reckoned using a 24-hour clock.

Don't ditch your watch, though; this method works only on clear nights! □

SKY ALMANAC

After comet Hale-Bopp all but overshadows tiny Mercury, turn your attention to the other planets and members of a giant galaxy cluster.

by Martin Ratcliffe

April sees comet Hale-Bopp finally reach perihelion, its closest approach to the sun. This marks the nearest it's been to our star's warmth in several thousand years.

Accordingly, Hale-Bopp's surface is alive with activity. Jets and geysers blast thousands of tons of gas and dust into space each second to create a resplendent tail. Usually a comet's close passage isn't easy to spot, but comet Hale-Bopp's path takes it far north of the sun, offering a perfect view for Northern Hemisphere observers.

For observers in the middle latitudes, in early April Hale-Bopp stands 20° above the horizon at the end of evening twi-

light. Look quickly; it sinks as the month unfolds, appearing a little lower at the same time each consecutive evening.

Watch Hale-Bopp's subtle beauty develop as twilight's glow recedes from the sky. The comet's bright coma is immediately recognizable as a fuzzy star, and as the sky darkens, a tail creeps slowly into view.

At this point, grab a pair of binoculars to aid your view. Rock them gently from side to side to trace the tail's fainter extremities.

Bright comets like Hale-Bopp are rare. Last year's appearance of comet Hyakutake might lead a newcomer to expect such displays every year. But

prior to 1996, the previous contender was comet West in 1976. So the sage advice is to make the most of this transient's visit from the depths of space. Even the moon cooperates for comet viewers by staying in the morning sky until well into the second week of April.

In an uncanny repeat of last year's visit by comet Hyakutake, comet Hale-Bopp lies in a similar spot on April 9 in Perseus, with the Pleiades nearby. Planetary mechanics places last year's Hyakutake companion, Venus, at superior conjunction with the sun on April 2.

Indeed, many sky-watchers treated last year's cometary spectacular as a dry run. This year, veteran and unseasoned photogra-

Highlights by Rick Shaffer

Date Event

- 5** Springtime for Mercury(p. 68)
- 18** The Moon and Mars Meet in Leo ..(p. 70)
- 30** This Spaceship Earth(p. 69)

all month:

First Views:

The Compleat Comet.....(p. 67)

Observer's Challenge:

The Frosty Leo Nebula(p. 68)
Get More from Hale-Bopp(p. 71)

phers alike will be clamping their cameras to photo tripods with visions of Hyakutake dancing in their heads. Add a bit of flair by positioning interesting subjects, such as trees or buildings, or even people, in the same frame as the comet.

During Hale-Bopp's visibility in early April, another object makes a fleeting appearance. **Mercury** lies due west at dusk, reaching its greatest elongation from the sun (19°) on April 5/6. April 8 offers a good chance to find this innermost planet of the solar system, as the very slim crescent of a two-day-old moon lies about 7° south of Mercury.

Get a jump on your search by scanning this

continued on page 69



Myron Wasiuta

Comet Hale-Bopp will grace the same area of sky as shown in this April 1996 photo of comet Hyakutake. This year Venus (upper left) is lost in the sun's twilight glare. Instead, look for Mercury nearby. Note the dipper-like Pleiades star cluster.

1997 A P R I L

- 1 The moon passes 4° north of Neptune, midnight EST
- 2 Venus is in superior conjunction, 9 a.m. EST
The moon passes 5° north of Uranus, 2 p.m. EST
- 3 The moon passes 4° north of Jupiter, 3 a.m. EST
- 5 The moon is at perigee (224,625 miles from Earth), 11:50 a.m. EST
Mercury is at greatest eastern elongation (19°), 8 p.m. EST (page 68)
- 7 New moon is at 7:02 a.m. EDT
- 10 The moon passes 0.5° north of Aldebaran, midnight EDT
- 13 Asteroid Iris is at opposition, 11 p.m. EDT
- 14 First quarter moon is at 1:00 p.m. EDT
- 16 Asteroid Amphitrite is at opposition, 4 p.m. EDT
- 17 The moon is at apogee (251,657 miles from Earth), 11:27 a.m. EDT
- 19 The moon passes 4° south of Mars, 2 a.m. EDT (page 70)
- 22 Lyrid meteor shower peaks
Full moon is at 4:33 p.m. EDT
- 25 Mercury is in inferior conjunction, 7 a.m. EDT
- 29 Mars is stationary, 2 a.m. EDT
The moon passes 4° north of Neptune, 7 a.m. EDT
Last quarter moon is at 10:37 p.m. EDT
The moon passes 5° north of Uranus, 11 p.m. EDT
- 30 The moon passes 4° north of Jupiter, 5 p.m. EDT (page 69)

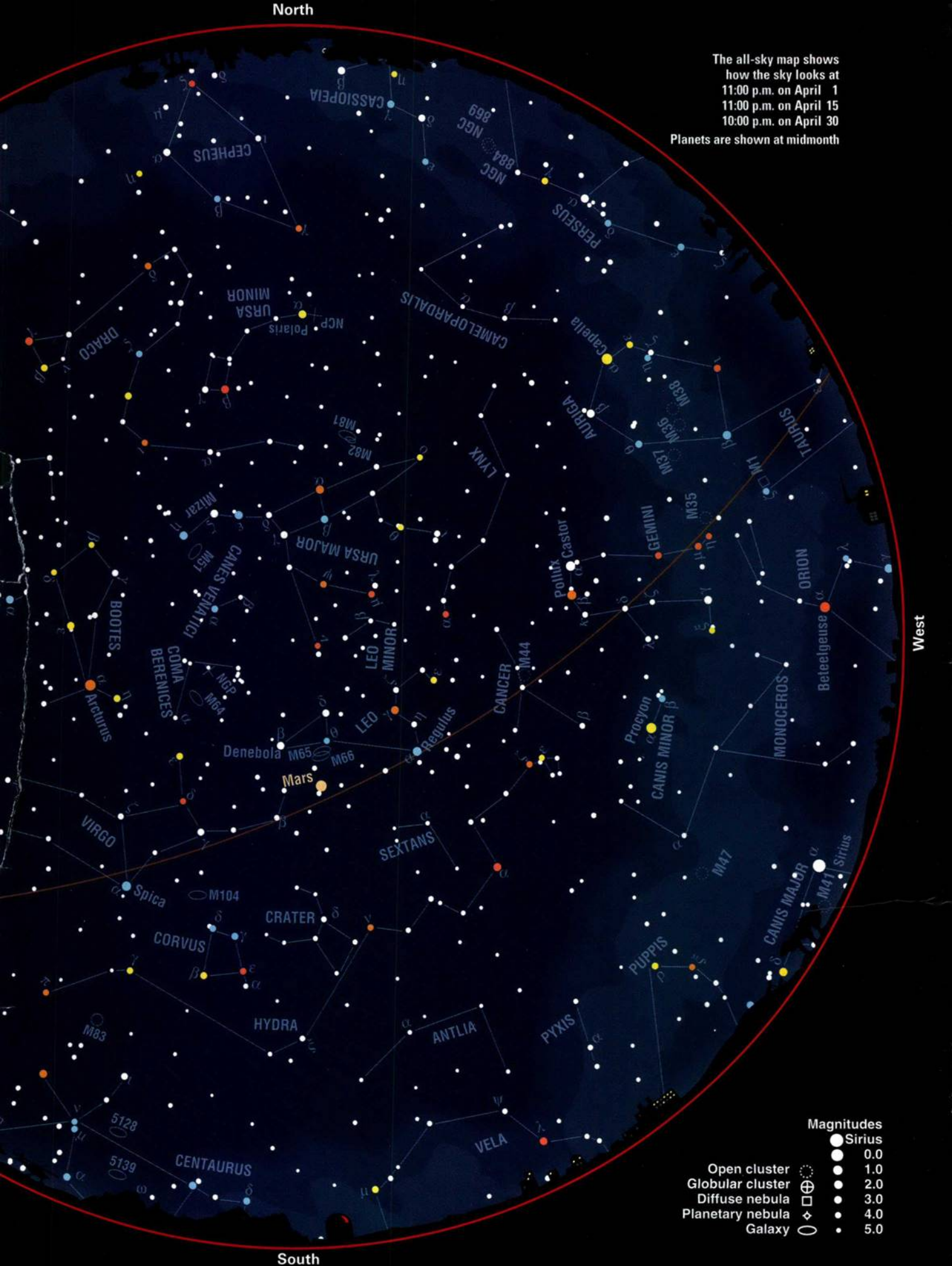
Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30			

This map portrays the sky at times shown in the upper right corner of the page. Located just outside the map are the four directions: north, south, east, and west. To find stars above your horizon, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.



North

The all-sky map shows
how the sky looks at
11:00 p.m. on April 1
11:00 p.m. on April 15
10:00 p.m. on April 30
Planets are shown at midmonth



West

South

Magnitudes

● Sirius

● 0.0

● 1.0

● 2.0

● 3.0

● 4.0

● 5.0

Open cluster

Globular cluster

Diffuse nebula

Planetary nebula

Galaxy



JUPITER

April 15
-2.1
36.5"
99%
5.396
5.101
21h20.0m
-16°09'



SATURN

April 30
0.7
16.1"
100%
10.333
9.436
0h54.9m
3°28'



URANUS

April 15
5.8
3.5"
100%
20.017
19.811
20h43.9m
-18°45'

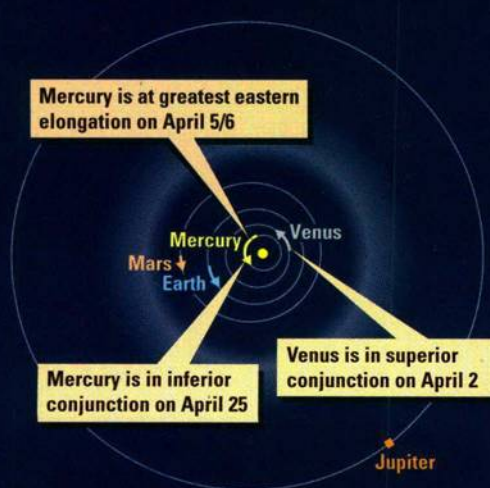
NEPTUNE

April 15
7.9
2.3"
100%
30.220
30.153
20h08.0m
-19°45'

PLUTO

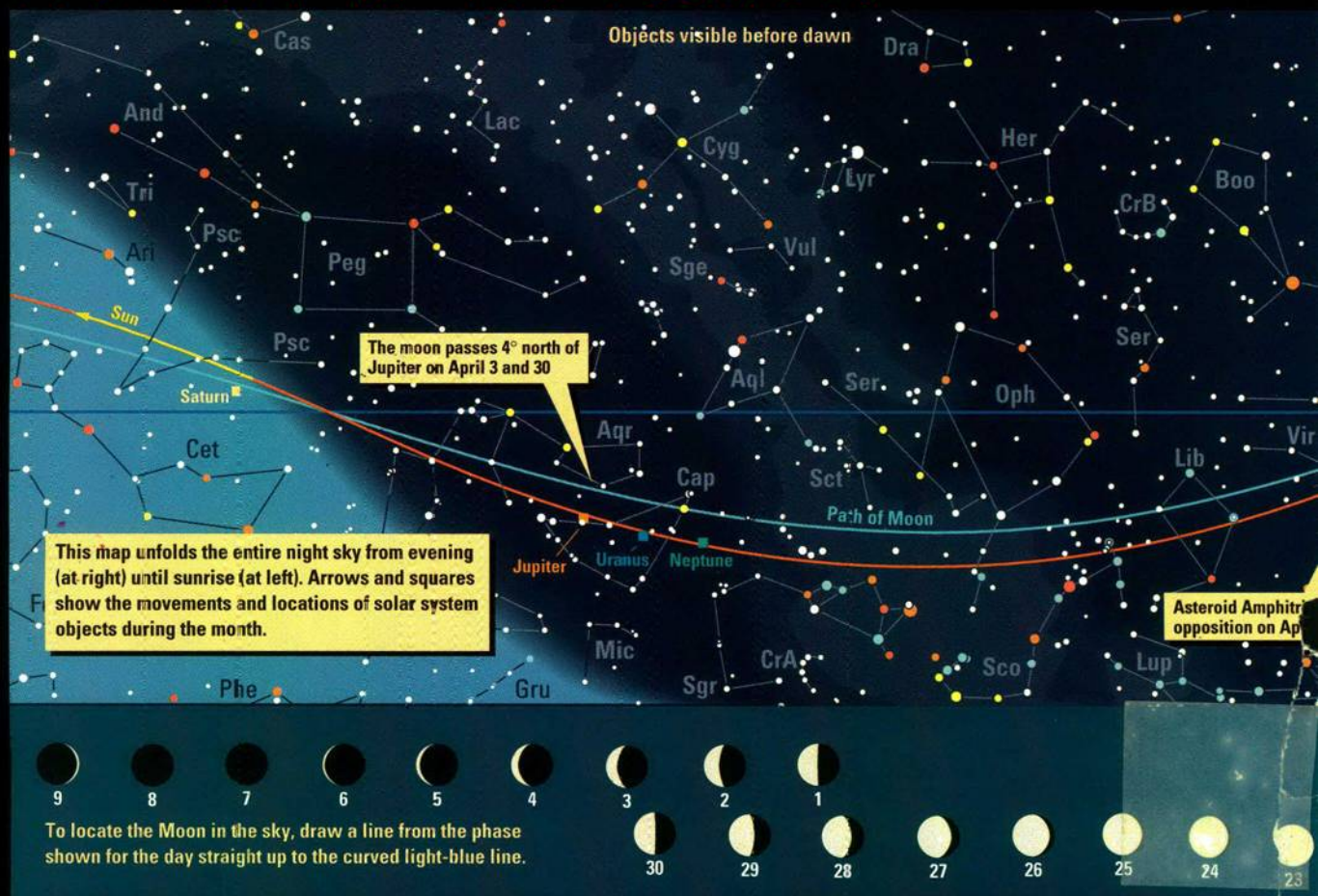
April 15
13.7
0.1"
100%
29.215
29.970
16h22.6m
-8°28'

THE PLANETS IN THEIR ORBITS



Arrows and dots represent planets' positions during the month.

THE PATH OF THE PLANETS



PLANETS

Date	Magnitude	Angular Size	Illumination	Distance (AU) from Earth	Distance (AU) from Sun	Right Ascension (2000.0)	Declination (2000.0)
April 1	-0.6	6.6"	60%	1.014	0.315	1h46.0m	12°57'
April 15	2.0	9.9"	13%	0.683	0.386	2h25.2m	17°35'
April 15	-3.9	9.7"	100%	1.723	0.724	1h46.6m	9°57'
April 1	-1.1	13.9"	99%	0.673	1.647	11h33.4m	6°26'
April 30	-0.5	11.6"	93%	0.807	1.626	11h14.6m	7°05'

MERCURY

Date	Magnitude	Angular Size	Illumination	Distance (AU) from Earth	Distance (AU) from Sun	Right Ascension (2000.0)	Declination (2000.0)
April 1	-0.6	6.6"	60%	1.014	0.315	1h46.0m	12°57'
April 15	2.0	9.9"	13%	0.683	0.386	2h25.2m	17°35'

MERCURY

Date	Magnitude	Angular Size	Illumination	Distance (AU) from Earth	Distance (AU) from Sun	Right Ascension (2000.0)	Declination (2000.0)
April 15	2.0	9.9"	13%	0.683	0.386	2h25.2m	17°35'

VENUS

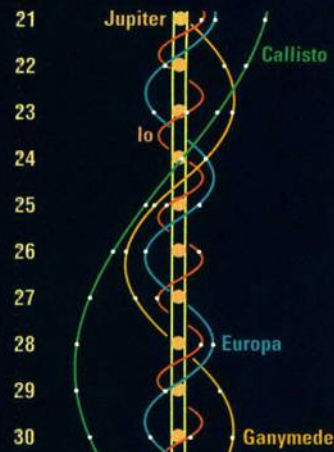
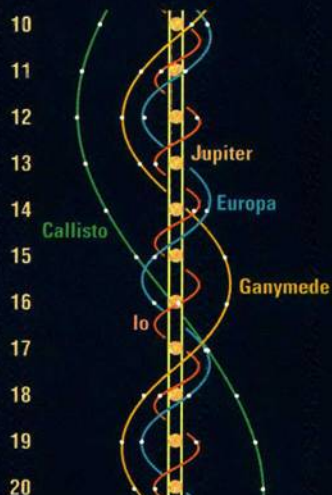
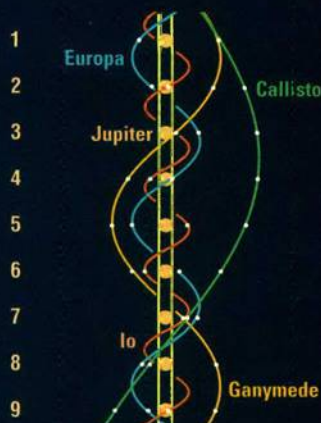
Date	Magnitude	Angular Size	Illumination	Distance (AU) from Earth	Distance (AU) from Sun	Right Ascension (2000.0)	Declination (2000.0)
April 15	-3.9	9.7"	100%	1.723	0.724	1h46.6m	9°57'

MARS

Date	Magnitude	Angular Size	Illumination	Distance (AU) from Earth	Distance (AU) from Sun	Right Ascension (2000.0)	Declination (2000.0)
April 1	-1.1	13.9"	99%	0.673	1.647	11h33.4m	6°26'
April 30	-0.5	11.6"	93%	0.807	1.626	11h14.6m	7°05'

JUPITER'S MOONS

Dots display positions of Galilean satellites at 3 a.m. EDT on date shown. South is at top to match the view in a telescope.



First Views: The Compleat Comet

As comet Hale-Bopp makes its swing past the sun, now seems the perfect time to present a primer on comets in general, and Hale-Bopp in particular.

Current theory says that comets are "dirty snowballs," flying mountains of ice mixed with dust and a bit of gravel that formed about 4.5 billion years ago when our solar system was born. The typical comet nucleus is $\frac{1}{2}$ to 3 miles in diameter. Comet Hyakutake's is probably a mile in diameter. Comet Halley has a peanut-shaped nucleus that measures 5 by 5 by 16 miles, while that of Hale-Bopp is thought to be between 15 and 24 miles.

As these comets formed billions of years ago, the gravity of the giant planets either kicked them into the inner solar system, where they bombarded Earth and other planets, or out into a spherical cloud that surrounds our solar system. This Oort Cloud, theorized by the Dutch astronomer Jan Oort, extends almost a third of the way to the nearest stars.

Occasionally, two cometary bodies orbiting in the Oort Cloud come close enough to one another for their mutual gravity to cause one to fall toward the inner solar system. The lucky comet falls inward at an enormous velocity, rounds the sun, and then barrels back out, taking eons between passes. A chance encounter with the gravity of Jupiter or Saturn could alter its orbital period to only a few years.

Comet Halley likely



A Comet's Actual Size

Comet Hyakutake on April 17, 1996/Jeff Peronto

started out in the Oort Cloud, only to have its orbit shortened by a close approach to a giant planet. It now orbits the sun every 76 years. Comet Hale-Bopp's orbital period of 2,100 years tells us it still journeys to the inner fringes of the Oort Cloud. This means its farthest point from the sun is 328 times Earth's mean distance from the sun. So far Hale-Bopp remains relatively unmolested by the gravity of our solar system's gas giant planets.

When a comet



In March 1986 the European space probe Giotto flew within a few hundred miles of comet Halley to reveal a peanut-shaped nucleus erupting with geyser-like activity.

approaches the sun, light and heat evaporate a top layer of ice directly into a gas through a process called sublimation, releasing any trapped dust and gravel. The liberated gas and dust concentrate into a halo around the solid nucleus called a coma.

When we look at a comet under high power, we see a star-like nucleus near the center of the coma. We're not seeing the actual nucleus, but rather a fog of gas and dust given off by the nucleus that shrouds our view. With very active comets like Hale-Bopp, we might also see jets or fountains of material extending from the invisible nucleus into the coma.

The coma of a comet can range from 120,000 to 1.2 million miles in diameter. Thus, as it approaches the sun, a puny object only a few miles in diameter is responsible for a temporary, very tenuous "atmosphere" as big or much bigger than the planet Jupiter.

You can see this atmosphere thanks to ultraviolet radiation from the sun that ionizes gas in the coma and makes it glow. The solar wind, a stream of charged particles flowing outward from the sun, carries this glowing gas straight back from the nucleus and away from the sun to form an ion tail.

Each particle of dust released by the sublimating ice assumes its own orbit around the sun, almost always different from that of the comet's nucleus. Because the dust is very light, it often trails behind as a gracefully curved dust tail.

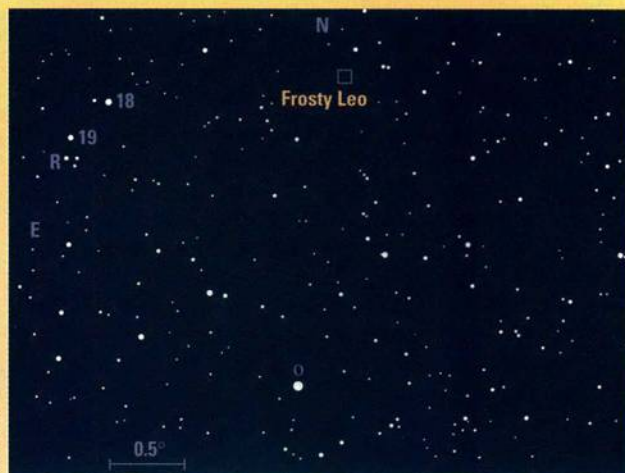
Although the tail of a comet can extend as much as 93,000,000 miles, the distance from Earth to sun, it is even more tenuous than the coma. In fact, using the word "tenuous" is being generous; the tail is about as dense as a good laboratory vacuum. In 1910, Earth passed through the tail of comet Halley, with no apparent effect. — Rick Shaffer

Max-Planck-Institut für Astronomie

Observer's Challenge: The Frosty Leo Nebula



Tim Puckett



Just a little more than a year ago the astronomy Internet newsgroup sci.astro.amateur was abuzz with a “new” deep-sky object. Backyard observers are always looking for challenges, and they seemed to have found one in newly coined “Frosty Leo.”

According to information posted by veteran deep-sky observer Brian Skiff of Lowell Observatory, this object is a reflec-

tion nebula surrounding a cool giant star of spectral type M0. The nebula is driven by a strong bipolar outflow of water ice from a region around the star. Hence, what better name for such an object in the constellation Leo than “Frosty Leo?”

As the accompanying map shows, Frosty Leo lies about 2° north and slightly west of the magnitude-3.5 star Omicron (o) Leonis. The nebula’s

11th-magnitude parent star is GSC 0824-1094, at 9h39.9m, 11°58.9' (2000.0). The surrounding nebula is spread over an area of sky approximately 15" by 25".

Skiff has observed Frosty Leo with a 22-inch telescope. Neither the night on nor the telescope were particularly good, so he says others should see Frosty Leo with better, even smaller, optics under darker, steadier skies.

Fellow deep-sky observers Russell Lederman and Rich Jakiel also saw Frosty Leo through similar-sized reflectors working as low as 125x.

However, both mention that high power shows the nebula as a half-moon or “cusp” shape, with a notch in the west side. They also say that using light pollution reduction filters yielded no advantage when viewing Frosty Leo. — R. S.

Springtime for Mercury

Mercury shines at its best for 1997 on the evening of April 5. Look for it 10° above the western horizon 40 minutes after sunset, a bit to the left of Hamal, Alpha (α) Arietis. The Pleiades are about 25° above this shy planet. Mercury remains above the evening horizon until around the 21st, when it starts passing into the sun’s glare.

On the evening of April 8, Mercury stands just 7° to the right of a two-day-old moon. Compare Mercury’s yellowish color with the moon’s gray by simply panning an altazimuth telescope back and forth from one to the

other. Mercury’s yellow color is evidence of its rough surface. Surface roughness scatters away more blue light than red from our line of sight, giving the planet a distinct pale-yellow cast.

The moon and Mercury have a lot in common. Both are bleak, cratered worlds lacking enough gravity to hold an atmosphere. They both rotate very slowly, although only the moon is tidally locked with Earth so its day is the same amount of time it takes to complete one orbit around our planet.

On the other hand, Mercury rotates once in 58.65



All illustrations by Astronomer: Elisabeth Rowan

days, while its “year” is 87.969 days. Thus, it rotates thrice as it revolves twice around the sun, strongly suggesting that there’s some sort of tidal-coupling effect at work.

The workhorse space-

craft Mariner 10 photographed craters on Mercury in the mid-1970s. If you want to see them, look at the pictures, for seeing them from Earth through a telescope is impossible. — R. S.

This Spaceship Earth



The last morning of April finds a last quarter moon near Jupiter in the morning sky, which sets up a perfect opportunity to take an imaginary trip into our solar system.

Start close to home, with the last quarter moon some 230,000 miles away. It occupies space in its orbit around Earth where we will be in about 90 minutes' time in our orbit around

the sun. Earth moves along at about 2,500 miles per minute, traveling its diameter in about $1\frac{1}{2}$ minutes.

That seems fast. If we could disconnect Earth's gravitational tether to the sun, we could shoot our planet on a little expedition to Jupiter.

First, Jupiter is 5.15 AU from us on the morning of April 30, or 2,070 times farther than the moon. So,



it would take us $2,070 \times 1.5$ hours, or 3,105 hours to get to Jupiter. That's 18½ weeks.

Once we get there, our troubles would be just beginning. Jupiter harbors one of the most intense radiation environments in

the solar system. And, because Jupiter's surface gravity is 2.54 times Earth's, we'd get squashed if we didn't get horribly irradiated.

Fortunately, nobody can diddle Earth's gravitational tether. — R. S.

continued from page 62

part of the sky with binoculars after sunset. The planet will be a challenge, shining at a respectable magnitude of 0.2, but in a bright, twilight sky.

During this evening apparition, Mercury is brighter before it reaches greatest elongation (it shines at magnitude -0.6 at the beginning of April) and easier to pick out during dusk.

Once comet Hale-Bopp and Mercury set, you may be asking yourself what else there is to view in the night sky. Well, plenty. Once the sky gets truly dark, start a journey through Virgo's rich cache of galaxies.

Locate Virgo by turning a full 180° from where the comet was visible. By 9 p.m. local standard time (10 p.m. daylight) Spica, the 1st-magnitude leader of Virgo, sparkles 20° above the east-southeastern horizon.

High above Spica, and outshining it by more than a full magnitude, is **Mars**, a brilliant magnitude -1.0 in early April. Draw a line between Spica and Mars. North of this line lies a realm rich in galaxies called the Coma-Virgo Galaxy Cluster.

It's hard to visualize a giant cluster of galaxies if you've never seen one before. From reading popular literature, a newcomer could be forgiven for expecting to see a brilliant swarm of spiral galaxies filling an eye-piece's field.

The reality is that galaxies lie millions of light-years away. The light you may see tonight left long before humans walked on our planet.

Understandably, then, galaxies are faint objects, elusive smudges of light requiring a good telescope and patience to glean. Therein lies their magnetic attraction to observers:

Light from billions of stars has journeyed across the universe, uninterrupted for eons, until it strikes the eye.

Virgo holds some of the easiest members of a galaxy cluster to observe, though a good star atlas is a must to help guide you. The brightest members of the Coma-Virgo Cluster are generally elliptical galaxies, all listed in the well-known Messier catalog and denoted by a capital M followed by a number.

A good starting place is Rho (ρ) Virginis, a 5th magnitude star just inside the left arm of Virgo, some 5° west of 3rd-magnitude Epsilon (ϵ) Virginis.

M59 and M60, a pair of 10th-magnitude elliptical galaxies, lie within the same low-power field of view a degree north of Rho. Many other galaxies lie to the northwest of this pair. A 4-inch reflector should locate them fairly easily.

If faint objects don't whet your appetite for

observing, then the dazzling red orb of Mars surely will. It is the second-brightest "star" in the sky after Sirius, which currently lies over in the southwest. Its present $13''$ apparent diameter allows you to see detail on its surface through a medium-sized scope. Can you still see its tiny north polar cap or the dark shadings that cover its desert landscape?

Mars lies near the hind legs of Leo the Lion, where its retrograde, or westerly, motion against the background stars slows to a crawl by the end of April.

Check out the contrast in color between Mars and the other bright stars in the sky, namely Spica, Regulus in Leo, and the stars of Orion over in the southwest.

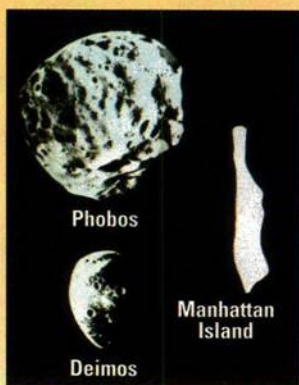
A waxing gibbous moon easily outshines Mars when it passes 4° south of the Red Planet on the night of April 18. The magnificent brilliance of

The Moon and Mars Meet in Leo

On the evening of April 18, our moon passes just 4° south of Mars in the western sky. Aside from the obvious aesthetic appeal, the conjunction serves to remind us that Mars still presents a reasonable telescopic target, with an apparent diameter of 12.6".

Seeing Mars so close to the moon allows us to stretch our collective imagination a bit. The Apollo expeditions have shown our moon to be lifeless. But what of Mars?

A century ago, scientists almost accepted life on Mars as a given. Percival Lowell even imagined canals being constructed on an arid planet by a dying race. Investigations by spacecraft in the 1960s and 1970s revealed a dry planet barely able to hold on to a carbon dioxide



atmosphere. Two decades ago, we sent two landers in hopes of clinching signs for life.

Today we have evidence from a martian meteorite suggesting microorganisms may have lived on Mars billions of years ago. This begs the question, Are there Martians today?

Actually, martian life may have had only a slim chance of evolving, at least



into the kind of life we might imagine. The reason? Mars' puny moons Phobos and Deimos. Their small size (see comparison box) generates almost no tides at all. The kind of mixing that Earth's tides caused as life was making

a start could not have occurred on Mars.

Might another mechanism have stirred things up enough to get martian aquatic life established on martian dry land? Perhaps the answer will come in our lifetime. — R. S.

Taurus, Orion, Gemini, and Canis Major owe their splashiness to such luminaries as white Sirius, slightly yellowish Procyon, sapphire-colored Rigel, and ruby-red Betelgeuse and Aldebaran.

Note how the winter stars are making their last appearance in the western sky. The bull and the hunter sink together in the west by late evening, followed by the twins and the little dog after midnight. Face northwest along the line of the Milky Way during midevening to find Auriga the Charioteer, its yellow sun of Capella vying for attention.

Neighboring Perseus lies below and to the right of Auriga — a fine region to scan with binoculars. Farther to the right is W-shaped Cassiopeia the Queen, now descending to a low point above the

northern horizon. Adjacent to Cassiopeia lies Cepheus, the mythological king of Ethiopia, seemingly holding his queen's hand as they swing beneath Polaris.

Facing north, tilt your head back until you find the familiar Big Dipper overhead, the brightest part of Ursa Major. Its 2nd-magnitude stars are well-known, but the group also contains superlative examples of deep-sky objects. Try out a pair of 7th-magnitude galaxies with a small telescope, the spiral M81 and the celebrated irregular galaxy M82. Both lie to the northwest of Dubhe (Alpha [α] Ursae Majoris).

The Owl Nebula, M97, one of the finest planetary nebulae in the heavens, lies within a few degrees of Merak (Beta [β] Ursae Majoris) along a line towards Phecda (Gamma [γ] Ursae Majoris). The face-

on spiral galaxy M101 is rather faint. It forms an almost exact equilateral triangle with the last two stars in the handle of the dipper. Check out the second to last star in the handle; it is a naked-eye double star of Alcor and Mizar.

This duo was often used to test the eyesight of soldiers in ages gone by, and remains a good test today. Mizar, at magnitude 2.3, lies 80 light-years from Earth; 4th-magnitude Alcor is two light-years beyond it. Their coincidental alignment along our line of sight only makes them appear as a double star.

Re-enact the discovery of the first telescopic double star in 1650 by noticing another 4th-magnitude companion much closer to Mizar. In this case, the two are physically associated with one another. Any small scope will split them.

Mizar also provided history's first spectroscopic binary star in 1889. Spectroscopic binaries are detectable only by examining a parent star's spectral lines for evidence of close-in, invisible companions.

After splitting Alcor and Mizar with your naked eye, and then splitting Mizar with a telescope (forget the spectroscopy!), try ranking each of the seven stars in the Big Dipper by brightness. This is harder than you might think, and will help hone your ability to gauge how bright things look in the night sky. Make your estimates before consulting a star catalog. Estimating the Big Dipper sequence could be a good project at a star party.

Another star party challenge is **Pluto**. It rises in the late evening, but it's best to wait until past midnight before viewing it

through a telescope. The early morning hours put it above any significant atmospheric dimming effects that occur when an object is less than 20° above the horizon. Another player that complicates Pluto observing, the moon, is out of the way early in the month.

Pluto glows feebly at magnitude 13.7, which is detectable in an 8-inch telescope provided you have a transparent sky and an accurate star chart of its current position. The best way to nail Pluto's position is to make detailed drawings of the suspected field of view. Revisit the same star field a few days later to see which object moved. The culprit will be Pluto.

Almost as fleeting are this year's Lyrid meteors. Their host constellation, Lyra, climbs higher in the northeast with each hour after midnight. But the Lyrids peak on April 22, which happens to be the same night as the full moon. Stalwart meteor observers will still catch some of the brighter members of this relatively scant shower.

If you're out in the predawn hours trying to catch a Lyrid or two, direct your attention towards a trio of outer solar system planets. **Jupiter, Uranus, and Neptune** congregate in Capricornus and eastern Sagittarius during these spring mornings. Only one of them, Jupiter, is easily visible to the unaided eye.

Watch a waning crescent moon glide past brilliant Jupiter between the mornings of April 2 and 4. You'll find the planet shining at magnitude -2.1 , low in the southeast, rising two to three hours before the Sun.

Meanwhile, Uranus and Neptune continue to separate after a close conjunction in 1994. Uranus lies well within Capricornus,

Get More from Hale-Bopp



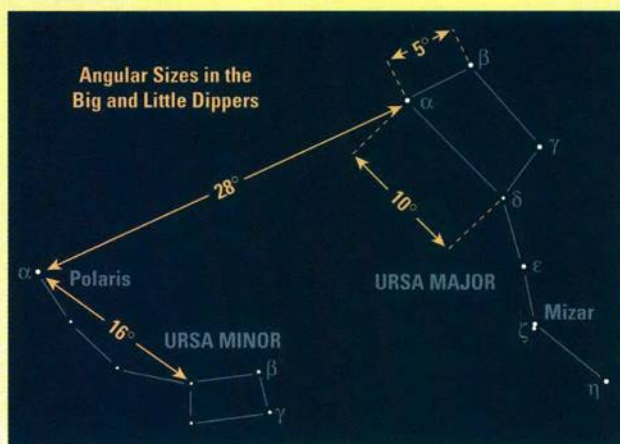
Hale-Bopp on Nov. 27, 1996/Tim Puckett

To borrow a phrase from the late W. C. Fields, this box offers a "veritable plethora" of last-minute hints for getting the most out of observing comet Hale-Bopp.

Get Powerful. Use as high a power as possible to scrutinize the region around Hale-Bopp's inner coma. This gives you a shot at seeing any fountains or jets of material being given off by the nucleus. Don't expect to see these features actually moving. That will take as much as a half-hour's time to notice. Try sketching what you see every 15 minutes.

Get moving. Hale-Bopp should be bright and easy to see within a few degrees of its coma. However, most of the comet's faint, broad tail will extend several degrees. Your eye-brain combination detects large, dim objects much better if they're moving. To "move" the tail of a comet relative to your

while Neptune just manages to slip into the seagoat the first week of April. By the end of April these two distant wanderers rise shortly after midnight. Look for them using binoculars or any telescope. Uranus is brighter at 6th magnitude; Neptune



field of view, simply sweep binoculars back-and-forth across the tail. Sweeping with the naked eye works best if you construct a cardboard viewing hood to block out stray light. Make it about a foot long and give it an open end about $2\frac{1}{2}$ by 7 inches. Shape the end through which you look to match the contours of your face. Paint the inside of the box black, or line it with felt or black construction paper.

is two magnitudes fainter.

The remaining gas giant planet, **Saturn**, is lost in the sun's glare during April, having passed through its conjunction with the sun last month. You may catch a glimpse of it in the eastern sky towards the end of the

Get measured. Get a feel for Hale-Bopp's size by comparing it with several scales. A fist held at arm's length from your eye subtends about 10° . The width of a thumb, about 2° . A fist and an extended thumb covers about 15° . An open hand at arm's length spans about 18° of sky. Look north to Ursa Major (the Big Dipper) and Ursa Minor (the Little Dipper) for still more measures to figure Hale-Bopp's extent. — R. S.

month. May will officially open viewing season for the Ringed Planet. □

Martin Ratcliffe directs the Henry Buhl, Jr. Planetarium in Pittsburgh, Pennsylvania. Rick Shaffer is a science writer living in Cornville, Arizona.

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Rich Zepernick, Cresskill, NJ

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DEEP-SKY ASTROPHOTOGRAPHY

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U.S. Patent 4,473,636

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U.S. Patent 4,448,500

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5. LUMICON EASY-GUIDER (selection to left)
6. LUMICON 48mm DEEP-SKY FILTER \$199.50
This is essential for highest possible contrast. Contrast is boosted up to 3X for both color or black & white photos. The 3 photos in this ad showing the Helix Nebula, Horsehead Nebula and Veil Nebula were all made using a LUMICON 48mm DEEP-SKY FILTER.
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LUMICON Hyersensitized film is essential for good deep-sky astrophotography. Deduct 10% for 3 or more rolls (mixed o.k.). **No C.O.D.s.**

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Ektachrome 1600, fast slide film	24	\$14.95
Fujichrome RD100, fine grain slide	24	\$12.95
D-19 B&W Developer	1 gal.	\$6.95



Exit Stage Right

HALE-BOPP'S GRAND FINALE

Hale-Bopp's stellar companions provide unique opportunities for observers and sky-shooters alike.

by Tom Polakis

Since its discovery on July 22, 1995, amateur and professional astronomers have watched one of the most anticipated comets of the century make its journey toward the sun.

Its discovery is well chronicled. New Mexico comet hunter Alan Hale serendipitously found a fuzzy spot near the globular cluster M70 while casually viewing in Sagittarius. Minutes later and only a few hundred miles away, Arizonan Tom Bopp noticed a hazy glow in the field of the globular cluster. Both reported the object to the Central Bureau for Astronomical Telegrams, and it was designated C1995 O1; also known as Comet Hale-Bopp.

We have had 20 months to prepare for the comet's perihelion on April 1. This is its closest approach to the sun and Hale-Bopp will be near its brightest. With a little planning, you can come away with some stunning views and images of the comet.

The comet has passed a great number of astronomical objects since its discovery. This is due to a remarkable set of circumstances that has resulted in its never straying more than 20° from the plane of the Milky Way. However, Hale-Bopp didn't come into its own until the middle of 1996, when it became an easy binocular target. From May through October, Earth's orbital motion caused the comet to traverse the Milky Way from the northwestern corner of Sagittarius through Scutum and into Ophiuchus. There it reversed

direction against the stars, passing very close to M14, another globular cluster. As the sun closed in, the comet appeared to take a left turn along the Dark Rift of the Milky Way, then it disappeared in December's twilight glare.

Hale-Bopp returned to a dark sky during the cold winter mornings of January, where it appeared as an interloper in Aquila. During February and March, it passed through such Milky Way constellations as Sagitta, Cygnus, and Lacerta, conveniently becoming both an evening and morning object by mid-March. Now, in the beginning of April, it has finished its brief stint as a morning object and returned as a full-fledged evening comet, where it will pass from the northeast corner of Andromeda into star-studded Perseus before closing the month out in Taurus. If you plan to get a good look at Hale-Bopp, now is the time to do it. By mid-May at northern latitudes, the comet will be lost for good.

Why does the comet take such a strange path across the sky? It's mainly because our own planet doesn't sit still in the solar system. Earth never gets closer to Hale-Bopp than 1.3 astronomical units (about 120 million miles) — more distant than the sun. So most of the east-to-west rocking that has taken place is due to Earth's orbital motion. The rapid descent from north to south that we will witness in April, however, is a result of the comet's motion.

This is not a favorable apparition of the comet, since we are on

the wrong side of the sun for the best view during perihelion. Unlike last year's Comet Hyakutake, Hale-Bopp is bright because of its intrinsic size rather than its proximity to Earth.

Hale-Bopp's remarkable path along the Milky Way will pass through some very interesting star fields. This will present outstanding photo opportunities, many of which may be taken advantage of with very ordinary gear. And if photography isn't your thing, the comet will highlight some fascinating astronomical objects for telescopes and binoculars. Let's follow Comet Hale-Bopp through the month of April as viewed from the middle latitudes.

Tuesday, April 1 The month opens with Hale-Bopp in the northwest, one quarter of the way from horizon to zenith an hour and a half after sunset. The moon will not be in the sky, so it will be worth your commute to find an observing site with little or no city lights in the northwest. From a dark site, you should be able to spot the fuzzy glow of the comet between two naked-eye stars parallel to the horizon. The leftmost of these, just 2° from Hale-Bopp, is the star called Almach, or Gamma (γ) Andromedae. A small telescope at 50x will reveal this gorgeous double star whose 2nd- and 4th-magnitude components are orange and blue gems separated by 10".

The comet's tail will be reaching into the northern region of the Milky Way, where it may become lost in the glow if Hale-Bopp is

Where to Find Comet Hale-Bopp

Date	R.A. (2000)	Dec.	Mag.
April 2	2h06.78m	43°41'	-1.7
April 4	2h23.59m	42°43'	-1.7
April 6	2h39.36m	41°37'	-1.6
April 8	2h54.09m	40°26'	-1.6
April 11	3h14.26m	38°32'	-1.5
April 14	3h32.29m	36°31'	-1.3
April 18	3h53.37m	33°48'	-1.2
April 24	4h19.79m	29°45'	-0.8
April 27	4h31.11m	27°48'	-0.7
April 30	4h41.43m	25°54'	-0.5

Along with the date, this table provides the comet's position in **right ascension** and **declination** (epoch 2000.0), equivalent to longitude and latitude on the sky. The **magnitude** is a measure of the comet's brightness: the faintest stars visible to the naked eye glow at about magnitude 6, the brightest at magnitude -1.5. The brighter the comet gets, the smaller the number.

really putting on a show. A good gauge for tail length estimates may be found in nearby Cassiopeia. The prominent "W" stars Beta (β) and Delta (δ) Cassiopeiae are roughly 10° apart. Due to the sun-comet-Earth angle, the upper limit on tail length in early April is 48° . Binoculars will show the Double Cluster (NGCs 884 and 869) in Perseus 15° above and to the right of the comet.

Those interested in capturing this photogenic visitor should use a medium to long telephoto lens. Remember to place the comet's head in the corner of the frame and let the tail cross the field on a diagonal. Start your photographing as soon as twilight ends, before the comet sinks low into haze near the horizon.

Friday, April 4 For those with day jobs, Friday night should present a chance to get away from city lights to watch the evening show. History has shown that most comet photos are taken on Friday and Saturday nights. As if by design, this Friday night will present an excellent photo opportunity. Hale-Bopp will be situated less than a half degree from the classic edge-on spiral galaxy NGC 891.

Path of Comet Hale-Bopp



ASTRONOMY: Lee Van de Visse

This should be an extraordinary sight even though the duo will be only 20° above the horizon. Imagine this: in the same field of view as a comet 130 million miles away is the soft glow of a galaxy millions of times more distant. If Hale-Bopp's distance from us could be shrunk to one inch, this galaxy would be one-fifth of the way to the sun. NGC 891 is often used to represent the appearance of our own Milky Way Galaxy when viewed from the edge, and that view through a telescope can be stunning.

Although NGC 891 is faint, a 10-inch telescope at 150x at a dark site will show the glow to be about three times as long as it is wide, and reveal subtle hints of a dark dust lane reminiscent of the summer Milky Way's Great Rift. If you have access to a larger telescope, use it! And if you are set up to do photography or CCD imaging, you don't want to miss this chance. A telescope that provides a field of view of one degree or so, such as a 10-inch f/10, should show the bright core of the comet in the same field with the distant spindle. A more constricted field may result in cropping one of the two objects from the frame while a

wider field will result in loss of detail in the small galaxy. Again, the often underrated subject of photographic composition will be important. As the galaxy's long dimension is oriented in the same direction as the tail, it will be important to frame it diagonally opposite the head of the comet.

If you are simply out enjoying the view with your naked eye or binoculars, note how much the comet has moved since the previous night relative to Almach, which is now almost directly below it. As its tail is now passing through one of the fainter parts of the Milky Way, try to trace its length against the dark sky.

Saturday, April 5, and an Eclipse Treat To the unaided eye, Hale-Bopp will leave Andromeda and make headway into the rich star fields of Perseus. Before moonlight enters the scene, this will be a good time to make high-magnification observations of the inner coma. The unique jet structure that has been monitored for more than a year is sure to be well seen in April. Look for rays emanating from the bright core, and a plume that may be visible in the opposite direction as the tail.



Tonight is also the night when North Americans will be treated to an eclipse in the binary star system Algol. With a period just shy of three days, Algol dims by a noticeable 1.3 magnitudes due to an eclipse by a dimmer, orbiting companion. The eclipse lasts a couple of hours, with minimum occurring near the end of twilight for the United States. To find Algol, project a line just more than the distance from Almach through the

comet. At its faintest, Algol is magnitude 3.4, the same as Rho (ρ) Persei, 2° to its lower left. On every other night in April, the setting Algol will be shining much more brightly at magnitude 2.1, or about as bright as Almach.

Sunday, April 6 Having passed in front of a distant, edge-on galaxy, it's now time for the comet to narrowly miss a much nearer open cluster. The large scattering of

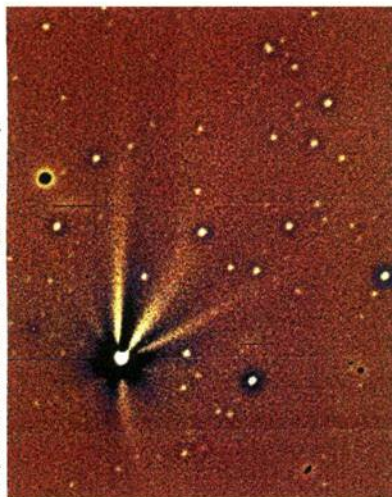
stars known as M34 will be only $1\frac{1}{2}^\circ$ away from the comet's head. And if that's not enough, Hale-Bopp's tail will pass in front of the cluster. Using a scale that places the comet one inch away, M34 would be 1,000 miles away. Rather than the large aperture required to see distant galaxies, this event certainly will be best seen with binoculars and small, rich-field telescopes.

M34 covers too much sky area for the constricted view of most telescopes, so you'll get your best view at magnifications of 10 to 30 times. The cluster is a scattering of

Hale-Bopp's jets have provided some of the most memorable images of this comet.

In October 1996 the comet inched its way through Ophiuchus.

Perry Berlind and Jane Luu (Fred Whipple Observatory)



Al Kelly



ASTRONOMY: Elisabeth Rowan

about 40 stars, many of which are within reach of 10x50 binoculars or a finderscope of similar aperture. This density of bright stars results in a cluster that shines at 5th magnitude and is quite easy to see in a dark sky without optical aid as a small hazy patch.

While the best photographic equipment for capturing both the comet and the cluster will be a short-focus telescope, telephoto lenses of 300mm or longer focal

On November 28, 1996, Hale-Bopp was captured just before its hiatus.

length should also provide a pleasing image.

Tuesday, April 8 As the sky darkens, it should become easy to see a nearly two-day-old crescent moon in the deepening twilight. Take a moment to look 7° to the right of the moon at the innermost planet Mercury. Our satellite's crescent is a sign that its light will begin to interfere with the comet soon. During the next several days, the comet is placed in a position in Perseus that is uncannily similar to the one occupied by Comet Hyakutake exactly one year ago.

Back then, Hyakutake was past its peak and receding fast, though it still displayed a magnificent tail more than 10° long. If Hale-Bopp is exhibiting a similar tail length, we can expect the tail too to be lost in the Perseus association — a wide grouping of 20 or so stars between Alpha (α) and Delta (δ) Persei. These are visible to the naked eye in good conditions.

Can you see the tail of this comet emerging from the other side of this group? This will be a good time to photograph the comet with a standard lens, as a well composed photo will include the Pleiades and the California Nebula 20° to the left along the western horizon.

Wednesday, April 9 The three-day-old crescent moon may begin to interfere. If the comet is bright enough, an interesting camera-and-tripod composition will include the thin crescent with the Hyades and Pleiades. Try a wide variety of exposure times. The best exposure will be a compromise between an overexposed moon and an underexposed comet. Note that the comet is now only 2° directly below Algol.

Thursday, April 10 The moon has now reached the same elevation as Hale-Bopp, setting at about the same time. It will be brightening the sky considerably, but not enough to preclude observations. In a few days, the "fill-in" lighting of the moon will begin to make for some most exciting photographs. Although possibly of only academic interest, the comet is several degrees below one of the sky's most interesting galaxy clusters, Abell 426.

Highlighted by the enigmatic 12th-magnitude peculiar galaxy NGC 1275, the cluster contains over 50 galaxies visible in a 20-inch telescope over an area only a couple of degrees across.

These are the most distant visible galaxies the comet passes in April. With the comet placed at one inch in our arbitrary scale, Abell 426 would be more distant than the sun. Perhaps the most adventurous astrophotographer will pick up detail in the comet's



Robert Siding

tail in front of this remote galaxy cluster in a great illustration of depth of field.

Monday, April 14 The first quarter moon will brighten up the sky while illuminating the foreground scenery. Mid-April presents a chance to turn moonlight into an advantage. Some of last year's most pleasing photographs of Comet Hyakutake featured a countryside basking in the glow of moonlight. This type of photograph requires only the simplest of equipment. A camera and tripod with a lens 50mm in focal length or wider will do the job. If you are using a standard 50mm lens, you can get away with an exposure of about 12 seconds before the stars start to trail — a bit longer if you aren't a purist about perfectly round star images. Use fast film and close down your aperture a half-stop or so to improve sharpness.

Wednesday, April 16 Bright moonlight will wash out the spectacle of Hale-Bopp's tail pointing vertically through the California Nebula. However, the waxing gibbous moon over the next several days will provide the best balance between landscape and sky.

Exposures of 10–30 seconds with a 28mm lens and fast film will result in an image similar to what the naked eye will see. A good composition with a standard lens will put the comet on the right side of the frame and include both the Hyades and Pleiades. Take several exposures for each frame, and double the exposure length each time.

Monday, April 21 Although the moon will be nearly full, the comet will be passing near yet another interesting deep-sky object. This time Hale-Bopp will be a degree to the right of NGC 1514, a bright planetary nebula in Taurus. An 8-inch telescope at 200x will show a complex 2' shell surrounding a 9th magnitude central star. Owing to this planetary's high surface brightness, it may be well photographed or imaged right next to the comet despite the bright background sky.

Tuesday, April 22 Continuing its trek into Taurus, Hale-Bopp will get even closer to NGC 1514, which is now situated $\frac{1}{2}^\circ$ below the comet's head. A short exposure may capture much of the inner detail in both the planetary and the head of the comet.

Thursday, April 24 The moon will have left the scene, and Hale-Bopp will have a dark sky for the first time in nearly two weeks. The time-window is short, however, because the comet will be spending less time above the western horizon with each passing night. Since the comet will be 25% farther away than it was at the start of the month, its re-emergence into the darkness should be less spectacular.

Hale-Bopp's tail will shrink to a maximum of just over 30° . Look for the Pleiades directly below the comet, halfway to the horizon.

Saturday, April 26 Hale-Bopp will be only 15° high in a dark sky, thanks to both the change of seasons and its southward motion. If the tail is 10° long, it will likely be lost in the fields of Auriga's Milky Way. The local area around Hale-Bopp will be star poor and



Gordon Garradd

A preview of the many photo opportunities to come: Hale-Bopp glided by M14 on October 29, 1996.

should showcase the comet nicely against the blank background.

Wednesday, April 30 April closes with Hale-Bopp less than a half degree above the obscure reflection nebula IC 2087. Situated in a nearly starless field, this 4' by 4' patch is visible in a 13-inch telescope, although the prospects for seeing it will be dimmed by low altitude. A good astrophotography set-up may capture the pairing; the last close passage before the comet disappears from view.

With only a few weeks remaining in its performance, Hale-Bopp exits April after an unprecedented show that has culminated after nearly two years. Additionally, its unique "encounters" with deep-sky objects make this the prime month to follow Hale-Bopp. □

Tom Polakis is an aerospace engineer for AlliedSignal Engines. He resides in Tempe, Arizona. His main astronomical interests are deep-sky observing and photography.

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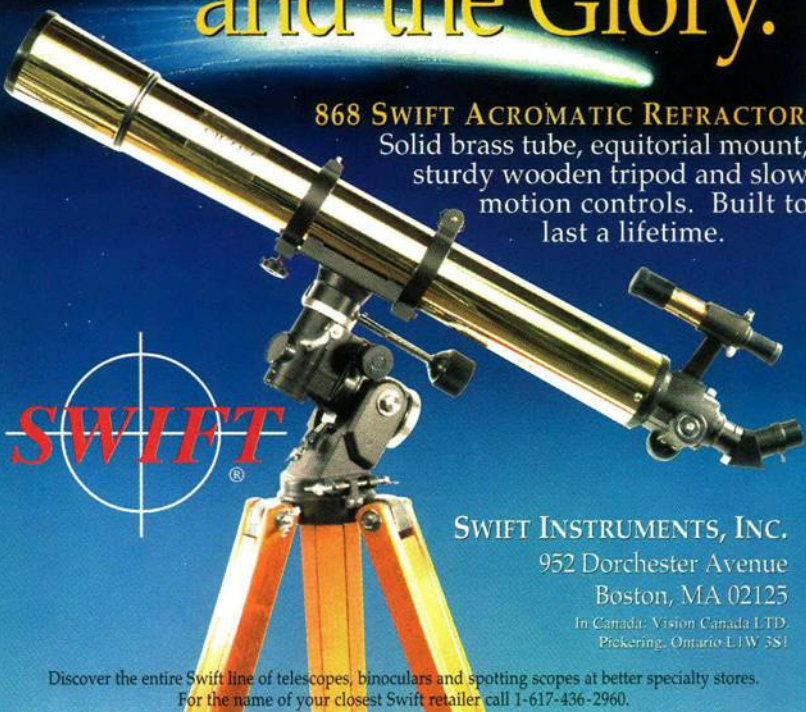
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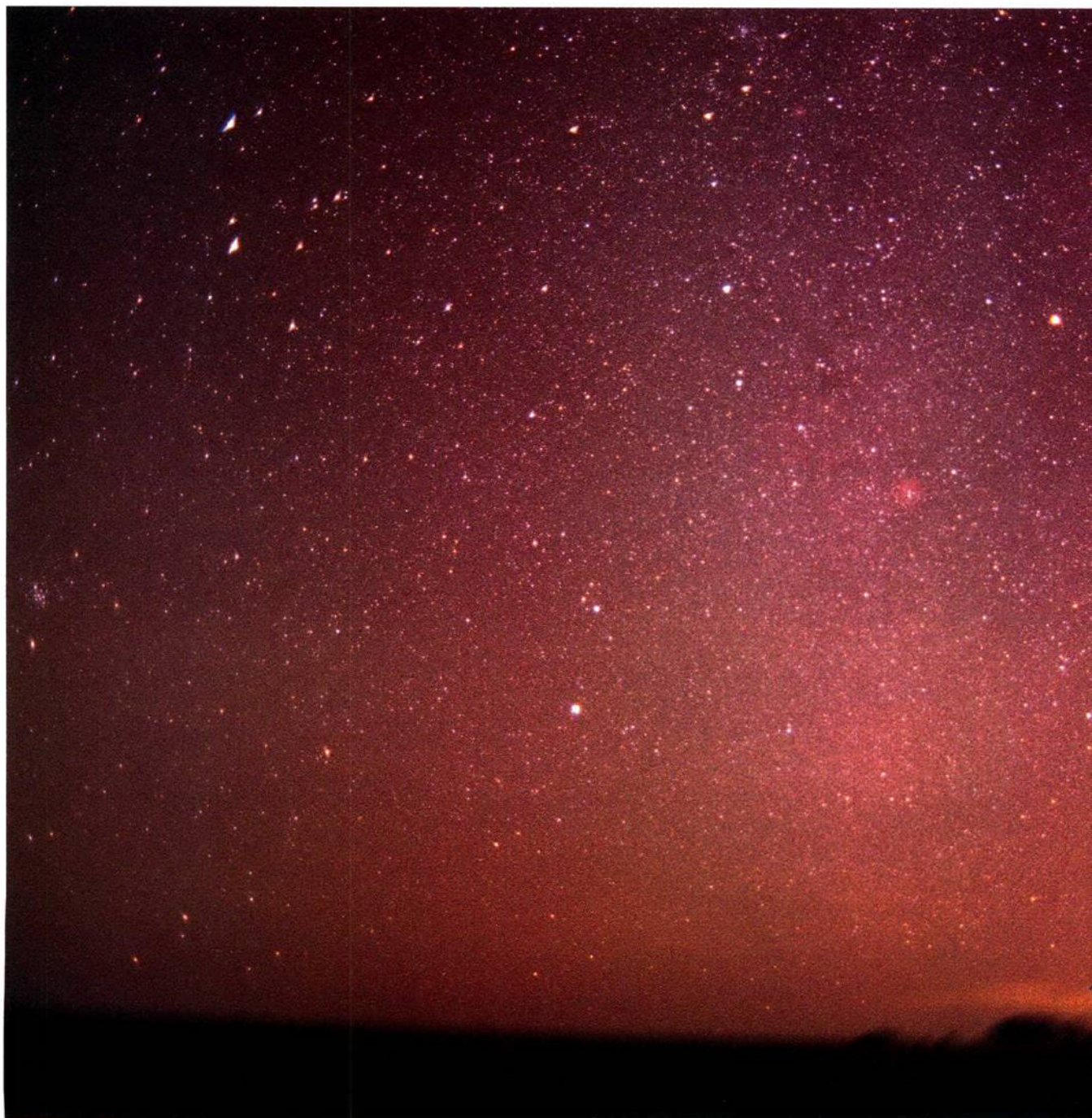
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Discover the Spring Sky

Take your 2- to 6-inch telescope on a journey of the imagination to the moon, planets, and galaxies.

by Glenn F. Chaple, Jr.



The moon is an astronomical neophyte's delight. It's big, it's bright, it's easy to find. And it's a magnificent small-telescope sight that leaves even veteran observers gasping in awe. What more could you want? Because you can easily get lost in the jumble of mountains, craters, and plains that dot the lunar surface, we'll start out with a view of the relatively uncluttered evening crescent moon.

Three or four nights after new moon, a thin crescent moon appears low in the west at sunset. (New

The spring sky offers a transition period between the rich winter Milky Way of Gemini (left) and Orion (right) and a stark, star-poor area filled with numerous faint galaxies.



Alan Dyer

moons occur this spring on March 8, April 7, May 6, and June 5.) Begin your lunar excursion with low power (around 30x), so you can scan the entire Moon and target features for high power study.

Look for a smooth, grayish oval near the middle of the crescent. This is Mare Crisium (Sea of Crises), a lava plain roughly equal in area to the state of Washington. A close look at Mare Crisium with medium magnification (75x to 100x) reveals two small pock marks. These are the craters Picard and Peirce, each about a dozen miles in diameter and over a mile deep. Small by lunar standards, they would be major tourist attractions here on Earth.

Want something larger? Train your eyepiece on the crater Cleomedes, located slightly north of the Sea of Crises. The entire state of Connecticut could fit inside this 80 by 90 mile wide pit. The floor of this sizeable crater is rough and contains several mountain peaks. Compare Cleomedes with the similar-sized craters Endymion and Langrenus.

Out to the Planets: Mercury and Venus

While paying your respects to the crescent moon, try to spot the elusive planet Mercury. On the evening

Mare Crisium, the moon's Sea of Crises, offers a smooth terrain pocked with a few craters visible through small telescopes.



Jean Dragesco

of April 8, 30 minutes after sunset, look for an extremely thin crescent moon about 15 degrees above the western horizon. Once you've found the moon (binoculars help, if the unaided eye fails), look directly to its right to see Mercury. On other nights, use Venus as your guide. Mercury is too near the horizon, where air turbulence is always a problem, to show much surface detail. Be satisfied that you've spotted a planet that relatively few people have ever seen.

A month or so later Venus reenters the evening sky. This brilliant white "star" will be much more recognizable than Mercury. Venus is the ideal "first planet" for beginners. Like the moon, Venus under-

goes phase changes, easily followed with magnifications as low as 30x. Keep tabs on this lunar charade by making weekly observations from the middle of May through the end of the year. Don't expect Venus to reveal spectacular lunar-like terrain. The planet is perpetually covered by a dense, cloudy atmosphere and presents an essentially barren white disk.

A Quantum Leap: The Stars

A telescopic journey to the stars holds the promise of a Star Trek adventure, but be forewarned. The typical star is hardly the visual treat the moon and planets are. No matter what magnification, all you'll see is a



tiny point of light (if you see a large disk, something is wrong with your focus). The stars are shrunk by distances typically a million times greater than the gap separating us from Venus or Mercury.

Stars may not look bigger than points through the telescope, but they appear brighter and more colorful than the naked-eye view. Set your sights on the bright, spring stars Arcturus and Spica — both found by extending the arc formed by the handle of the Big Dipper. Through a telescope, Arcturus is a rich golden-yellow — a definite contrast to the pure white of the

The galaxy M81 in Ursa Major reveals hints of its spiral arms to small telescope viewers only on the darkest, most steady nights.



Tony and Daphne Hallas

much hotter Spica. Experienced skygazers use the pinpoint images of stars to test the quality of a telescope's optics or the conditions of the night sky. For now, just enjoy the sparkle of these cosmic gems.

Not all stars shine with a constant light. Some pulsate like vast cosmic hearts, changing brightness a hundredfold in somewhat regular, months-long periods. These are the long-period variable stars — red giant stars going through old age instability. One of the best for small telescopes is R Leonis. This star varies from 5th to 10th magnitude and back in a 300-plus day cycle. What is R Leo doing tonight? Find out by traveling with your telescope to this interesting star. Chart R Leo's brightness changes with follow-up visits every 7 to 10 days.

Have you ever seen double, astronomically speaking? Although a single star may not be a particularly inspiring telescopic sight, the addition of a second or third star located nearby creates an almost magical vision. Look for Mizar (Zeta [ζ] Ursae Majoris), the middle star in the handle of the Big Dipper. Even without a telescope, you can see a tiny star (Alcor) next to Mizar. Mizar and Alcor appear at opposite sides of a low-power telescopic field, and a careful look at Mizar reveals an even closer companion. What a beautiful sight.

There's more. Ten degrees south of the Dipper is the star Cor Caroli (Alpha [α] Canum Venaticorum), visible to the naked eye. This stellar duo is slightly fainter and wider than Mizar. Study Cor Caroli with high magnification (75x to 100x is fine). Do you see a color contrast, or do both stars appear white?

Mizar and Cor Caroli comprise just the tip of the double-star iceberg. With a small telescope you can

Venus shines so dazzlingly bright it remains visible in the blue skies of daylight. It's shown here near conjunction.



Jim Baumgardt

Michael Stocker



Visible to the eye as a cloud of unresolved stars, the Beehive Cluster in Cancer (M44) offers a rich hunting ground for small scope observers and viewers armed with large binoculars.

view hundreds of stellar partnerships in a variety of magnitudes, colors, and separations.

To the Outer Limits: Deep-Sky Objects

If you think a double star is an impressive sight, wait until you glimpse the swarming suns of a galactic star cluster. On a clear, moonless night, look for a misty patch of light roughly midway between the Sickle of Leo and the twin stars Castor and Pollux in Gemini. With a low-power eyepiece in place, aim your scope skyward and hold onto your hat. The eyepiece field comes alive with stars — dozens, sparkling like lights on some cosmic Christmas tree. This stellar swarm is M44, appropriately nicknamed the Beehive Cluster. Star clusters, along with nebulae and galaxies, are often referred to as deep-sky objects. At a distance of over 500 light-years, the Beehive certainly fills the bill.

But 500 light-years isn't as "deep-space" as the 7-million-light-year distance of our final targets, the side-by-side galaxies M81 and M82. Search for them using a basic star atlas and a low power eyepiece.

Edge-on galaxy M82 in Ursa Major, which lies in the same low-power eyepiece field as M81, provides a stark contrast. Its mottled disk betrays a chaotic past.

Galaxies are so huge that, even at their great distances, they appear enlarged with low magnifications. Their stars, however, remain unresolved. Fuzzy and elongated, M81 and M82 both bear resemblance to comets. During the latter half of the 18th century, the French comet hunter Charles Messier sought out and cataloged a number of these comet imposters. M81 and M82 (and M44) are among the 100-plus entries in this historic work.

Because the two galaxies fit into the same low-power field, you can compare them. M81 is oval and slightly brighter than the spindly M82. As you gaze into the eyepiece, think about this: the light striking your eyes left these galaxies long before humans first appeared on Earth. The Ice Age was still six million years in the future. If a sense of awe overwhelms you as you study these remote misty patches, you are well on your way to joining the growing ranks of ASTRONOMY readers who regularly explore the heavens with a backyard telescope.

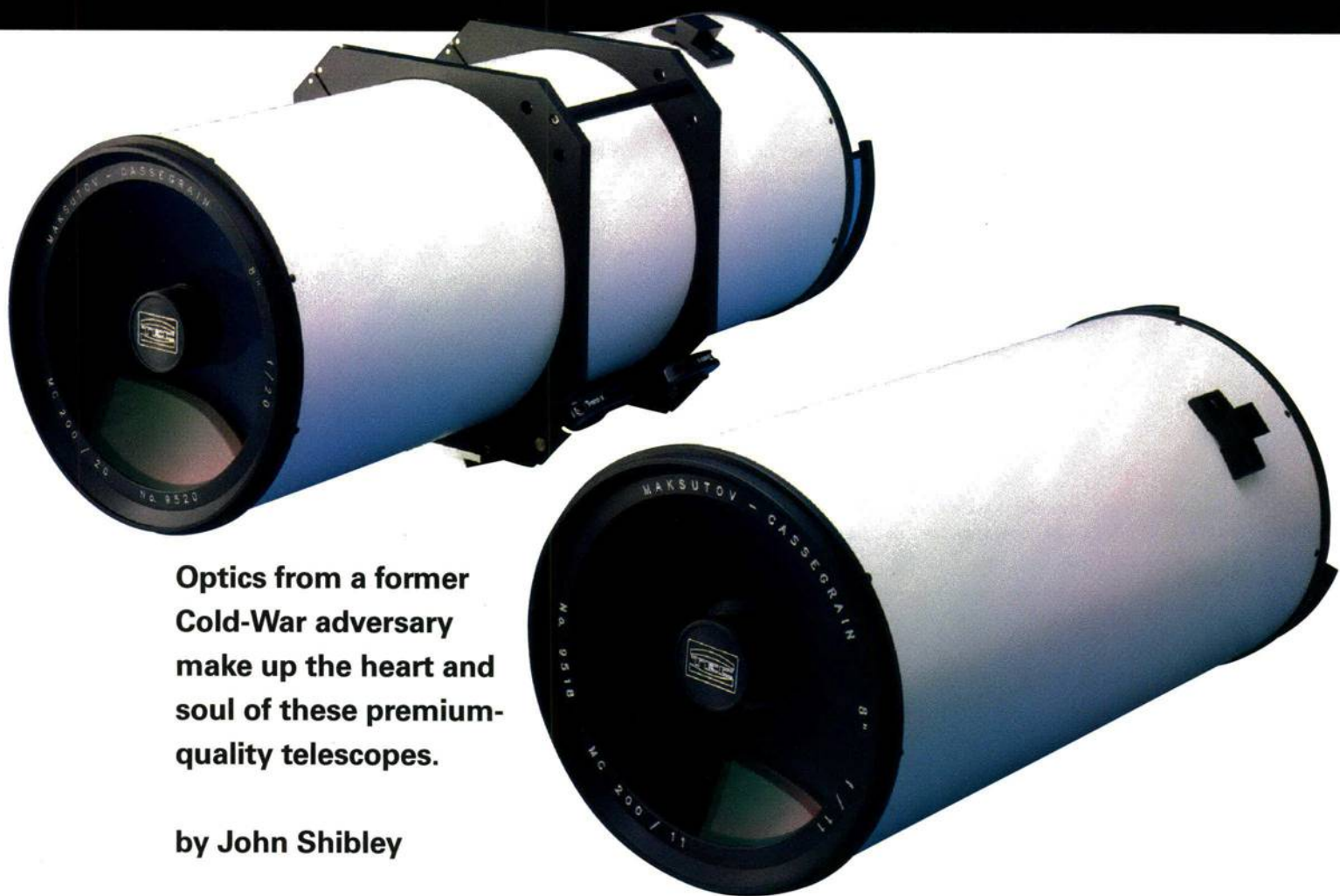
Spring is traditionally the season for beginnings. Let it be the season you get out under the stars and begin your small-scope adventure. □

Glenn F. Chaple, Jr. is a teacher living in Townsend, Massachusetts. He has written for ASTRONOMY and Deep Sky magazines, is coauthor of the Edmund Mag. 6 Star Atlas, and regularly observes with small telescopes.



Jack Newton

From Russia



Optics from a former Cold-War adversary make up the heart and soul of these premium-quality telescopes.

by John Shibley

One day it could happen. Your first telescope, after providing years of good service for a variety of uses in observing and photography, will seem to limit your enjoyment. You might be tempted to buy a more rock-steady or sophisticated mount. Or you could muse over a telescope where all the optical and mechanical components are optimized for a specialized area of observing or astrophotography.

Equipment that accommodates this higher degree of specialization comes at a price. Optics are hand-figured, and mounts are meticulously machined one by one. Where a capable scope runs several hundred dollars, a premium

scope could run several thousand. But for those who plan to be in this hobby for decades, such an expense isn't out of line. After all, quality does come at a price.

Over the past decade, this expectation has fueled a market for expensive, specialized, high-quality astronomical equipment. Niche companies have sprung up that make nothing but premium equipment. One such company is Telescope Engineering Company (TEC) of Lakewood, Colorado. They sell only telescope tube assemblies that attach to a mount you purchase from somebody else.

TEC offers a design called the Maksutov-Cassegrain, a type of scope renowned for its image qual-

ity and suitability for doing lunar and planetary photography. The company offers 8-, 10- and 12-inch versions. *ASTRONOMY* tried out an 8-inch $f/11$ (MC 200/11) and an 8-inch $f/20$ (MC 200/20), two tube assemblies that come with an international pedigree.

Maksutovs from Russia

TEC co-owner and designer Yuri Petrunin came to America about five years ago from the Soviet Union, where he worked on super-secret nuclear engineering programs in the Ural Mountains. Business partner Paul Kashtenko, a Russian émigré who's been in the States for more than 20 years, maintains close ties with a variety

With Love

of optical manufacturers throughout Russia and the Ukraine.

Kashtenko often travels to the former Soviet Union to discuss TEC's optical needs with a variety of suppliers. Optics that go into the company's Maksutov-Cassegrains are produced in match sets in shops primarily located in the Ukraine. Upon import into the United States, they are precisely collimated at high magnification and installed into tube assemblies. Most of the other components, such as mirror cells, focusers, baffles, and the tubes themselves, are made domestically.

TEC settled into making Maksutov-Cassegrains for good reason. This design approach lets them use a primary mirror with a concave surface determined by the radius of a circle. Such "spherical" mirrors have an advantage over "paraboloids," whose concave surfaces are described by a parabola. Spherical optics are easier to make. This ease of fabrication translates into a greater degree of quality control during all stages of grinding and polishing. Such optics are also easier to test.

But spherical optics have a greater chance of suffering from a variety of optical aberrations, no matter how tight tolerances are maintained during manufacture. One is spherical aberration, which, by the very nature of a spherical mirror, is always present to some degree.

This aberration prevents the light from a primary mirror from focusing sharply; an image suffering from spherical aberration won't appear sharp. Another aberration, coma, manifests itself in the outer edges of the field of view, creating stars that look like tiny comets rather than points of light.

Nobody, of course, wants to live with these shortcomings. Here's where the Maksutov cor-

rector plate comes into play. It's curved in the shape of a meniscus that bows towards the primary mirror. This curved corrector plate precisely bends and modifies light passing through it, eliminating any errors introduced elsewhere in the optical system by the spherical primary and mirrors.

By now, some of you may be thinking, "doesn't a Schmidt-Cassegrain deal with these problems?" The answer is yes, but not at the same level of simplicity a Maksutov-Cassegrain approach enjoys. For one, the Mak prescription calls for a primary optic and its secondary mirror, which directs light back to the eyepiece, with spherical surfaces. These surfaces are relatively easy to make at a high level of quality.

While a Schmidt corrector does go the distance in knocking down spherical aberration and coma, it must rely upon the help of a non-spherical secondary to get the job completely done. This adds another layer of complexity to the manufacturing process and requires a more complex regimen of tests. More quality problems can also creep in. Staying on top of these factors would drive up the

expense of producing a scope, hence the simple appeal of a Maksutov solution.

Lifting the Hood, Kicking the Tires

But all this theory is for naught if other components in the telescope assembly get short shrift. In this regard, TEC pays close attention to detail.

They select BK7 glass for the meniscus because its characteristics are well-suited for letting light through with a minimum amount of absorption and cost. Two thin layers of silicon dioxide (SiO_2) and titanium dioxide (TiO_2) anti-reflection coatings get applied to both sides of the corrector plate. The SiO_2 outer layer not only helps reduce reflections, it also offers a hard coating to resist scratches and withstand repeated cleanings. The combination of SiO_2 and TiO_2 also offers superior light transmission performance over magnesium fluoride, a coating more commonly used on optics.

Inside the telescope, both the

An optional 7x50 finder mounts on the tube assembly with a dovetail track.



All photos by Astronomer: Jim Forbes

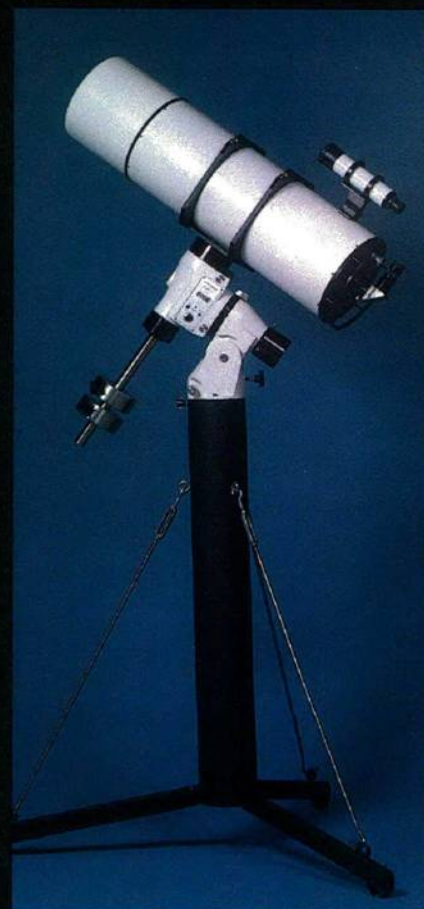
STANDARD SPECIFICATIONS

	MC 200/20	MC 200/11
Clear aperture:	8 inches (203 mm)	8 inches (203 mm)
Focal length:	4000 mm	2200mm
Length of tube (including front baffle):	34 inches	31 inches
Size of focuser:	up to 2 inches	up to 2 inches
Secondary diameter (with cell):	55mm	66mm
Secondary obstruction (by diameter):	26.5%	32%
Tube assembly weight:	26 lbs.	25 lbs.
Price:	\$3,330	\$3,300
Promised delivery date:	2 to 4 months	

OPTIONAL ACCESSORIES AND OTHER TELESCOPES

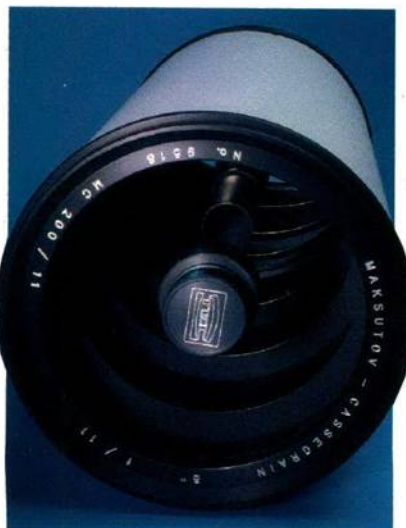
6-inch f/4 Maksutov-Cassegrain:	\$1,500
6-inch f/7 Richfield refractor:	\$2,200
8-inch f/4 Maksutov-Newtonian:	\$3,300
10-inch f/12 Maksutov-Cassegrain:	\$7,000 (also available in f/20)
7x50 finderscope:	\$80
Dovetail mount with base:	\$40
Tube mounting rings:	\$240
Focal reducer, 0.6x:	\$150

Telescope Engineering Company, Inc., 747 Sheridan Blvd., No. 4B, Lakewood, CO; (303) 274-7944; fax, (303) 274-4115.



primary and secondary mirrors are made of Sitall ceramic glass. This type of glass has an expansion coefficient of practically zero,

Interior baffles knock down internal reflection and reinforce the tube.



which means it doesn't expand or contract between extremes of heat and cold. A Sitall mirror holds its shape through a variety of temperatures to yield peak performance. Such thermal qualities also make the glass easier to work with during grinding and polishing for more consistent results.

To focus the telescope, you twist a knob on the back cell of the tube assembly. This controls an armature in the primary mirror cell that moves the entire optic back and forth to achieve focus. Physically, the mirror only moves over a range of 8 millimeters. However, one turn of the focusing knob moves the focal plane in the f/11 scope over a range of 5 millimeters; in the f/20, 14 millimeters.

A graduated, micrometer scale on the knob, available in metric or English measures, comes in handy for replicating exact focus, something an astrophotographer would find useful. Attention to detail

shows up in the form of a ruby that serves as the focuser's bearing. The bearing, 0.185 inches in diameter, provides just the right amount of resistance for a smooth focusing action.

Optically, both tube assemblies provided sharp, contrasty images. TEC includes a removable aluminum glare shield that slides over the telescope's front. The interior of each is coated with a textured layer of flat black, and comes with an impressive array of interior baffles that keep stray glare under control. (These baffles double as stiffeners for the 0.06-inch tube walls.)

Even the Mak's characteristically-shaped meniscus helps reduce the effects of stray light. A convex backside minimizes internal reflections, while the steep, concave front surface (versus a Schmidt corrector's flat plate) doesn't readily convey incidental light from the outside.



Both telescopes accept standard visual and photographic adapters. A carrying handle runs along the rear cell. The focuser (right photo) includes a micrometer scale to achieve precise, repeatable focus.



I tested each scope's ability to squelch glare by placing a waxing gibbous moon just outside the field of view. The view stayed relatively glare-free until the moon drifted into the field. This is all the more impressive when you consider the scopes' meniscus plates could have been a considerable source of internal reflection. Bright stars like Vega and Arcturus popped into sight with hardly a trace of attendant glare.

One testament of optical quality was the 8-inch $f/20$'s ability to split Epsilon (ϵ) Bootis. Discerning the double's 2.9" separation often proves difficult due to the primary star's magnitude-2½ brightness overwhelming the feeble light of a 5th-magnitude companion. But good optics — along with exceptional glare management — made the double a snap at 400x. The same proved true of Epsilon (ϵ) Lyrae, the famous "double-double." Both tube assemblies cleanly split ϵ^1 Lyrae (2.8") and ϵ^2 Lyrae (2.2") into disks surrounded by distinct diffraction rings.

Close examination of these diffraction rings on either side of focus betrayed an interesting characteristic unique to Maksutovs. Standard practice dictates that the measure of an optic's quality lies in how identical this diffraction

ring pattern looks on either side of focus. To my chagrin the Maksutov doesn't follow this maxim; the patterns are not identical, thanks to the corrector plate's influence.

But judging by the quality of the images, I can comfortably say that both scopes were working well within TEC's promised optical performance of $\frac{1}{2}$ wave or better. To soothe my concerns, I scrutinized both the mirrors with a 133 lines/inch Ronchi grating. Smooth, parallel, dark bands meant there were no residual aberrations or defects whatsoever in either system.

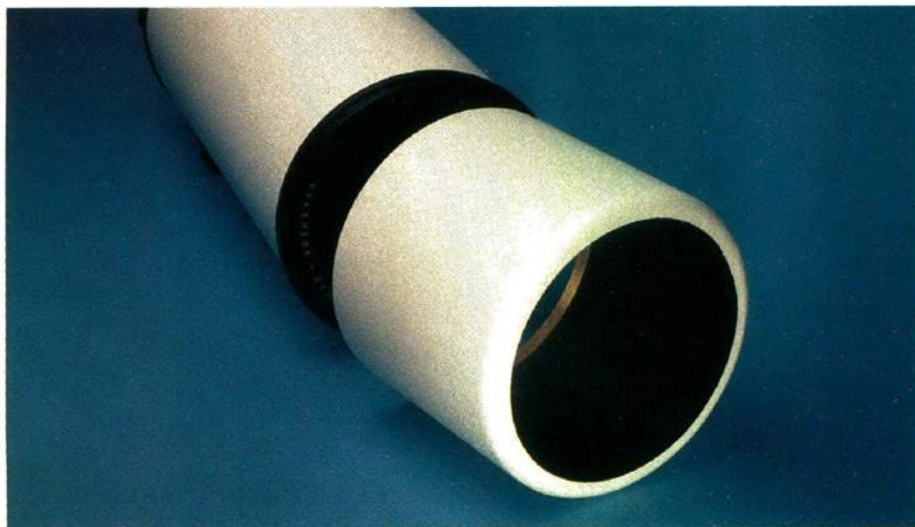
Why Not the Best?

Such performance comes as no surprise. When you buy premium optics, you're securing the services of a professional telescope maker to custom-build an instrument — not just a telescope — from

scratch. A finished product from TEC seems to rinse the universe free of all the dinginess of average optics. Cloud belts on Jupiter seem darker, craters on the moon look deeper, and double stars really look like doubles. At a cool \$3,300, such performance should be the norm from these scopes. (A good mount adds another three grand to the tab.)

So if the American consumer demands more from a car or sound system, and is willing to pay for it, why shouldn't the same apply to telescopes? If you're ready to "buy up" on the visual or photographic quality scale, then TEC's got a few telescope tube assemblies for you to consider. □

The dew cap/glare shield's rounded front edge minimizes air turbulence near the telescope's entrance.



With a large telescope you can spot star factories in distant galaxies from the comfort of your backyard.

by David Higgins

Spring means galaxies, and for observers there's no better treat than seeing the forms of these distant islands of stars with a backyard telescope. On dark, moonless nights, considerable detail awaits observers who gaze on the brightest and nearest galaxies. Perhaps the most challenging features visible are HII regions, clumps of ionized gas peppering the arms of spirals. These regions are vast clouds of hydrogen in which infant suns are being born.

The best opportunity to spot HII regions in the spring sky comes in the big constellation Ursa Major, near the Big Dipper asterism. There you'll find **M101** (NGC 5447), a popular target since the 18th century. This face-on spiral measures 26.9' by 26.3' and glows at magnitude 7.7. M101 lies at the end of the Big Dipper's handle and forms an equilateral triangle with 2nd-magnitude stars Mizar (Zeta [ζ] Ursae Majoris) and Eta (η) Ursae Majoris. Often used as a test for the transparency of the night sky because of its low surface brightness, M101 gives patient observers a good view of its well-developed spiral arms. But what sets M101 apart from most of its spiral brethren is the large number of HII regions that are visible to observers equipped with medium-size scopes, those in the 10-inch or larger class.

M101 has been observed by



Bill and Sally Fletcher

thousands of deep-sky watchers since its discovery in 1781 by the Frenchman Pierre Mechain. Lord Rosse, using his 72-inch speculum metal reflector, first mentioned M101's bright nebulous knots. These giant clouds of ionized hydrogen are bright enough to bear their own NGC numbers. I spent the better part of an observing season tracking down these objects, along with HII regions belonging to some of M101's cousins, using a 24-inch f/4 reflector. I spotted many of them but did not see others. But I had as much fun trying to see them as actually finding them.

NGC 5462 is the brightest of M101's HII regions. It lies on the eastern edge of the galaxy, is elongated north-south, and appears irregularly shaped. With a large backyard telescope and high magnification, NGC 5462 appears to be resolved into a clump of smaller nebulae. At least a 17-inch telescope is needed to separate them. Slightly northeast you'll find **NGC 5471**. This small, bright oval haze was easily seen with the 24-inch scope. A faint field star lies just east of the gas cloud.

The Pinwheel Galaxy, M101, holds 10 HII regions visible in backyard telescopes.

Move 3½' southwest of NGC 5462 to find **NGC 5461**. I spotted this elongated fuzz easily with the 24-inch scope. About 8' southwest of NGC 5461 you'll find **NGC 5458**. This nebula is listed as "nonexistent" in the NGC but I found an elongated, faint, irregular haze. It was visible with direct vision and appeared elongated north-south. Nearby lies **NGC 5453**. This irregular haze is elongated north-south and requires averted vision for the best view.

Move your scope 4' south of NGC 5453 to find **NGC 5455**. I picked up this small, bright oval with direct vision. Another "nonexistent" gas cloud can be found 5' northwest of NGC 5455. **NGC 5450** appeared as a small oval haze. I used averted vision for the best view. Three arcminutes north of this spot lies **NGC 5447**. This bright, irregular-shaped nebula is elongated north-south and was easily visible with the 24-inch scope. Just 2' north of here lies another so-called nonexistent neb-

ula, NGC 5449. I found it as a small oval haze and used averted vision for the best view.

The last of M101's HII regions is NGC 5451. Located about 4' north of NGC 5449, this small, faint oval haze required averted vision and a dark night. With the 24-inch scope I found some kind of glow at almost every supposed location of an HII region.

M101 may be the best galaxy with relatively bright HII regions, but it certainly isn't the only one. About $1\frac{1}{2}^\circ$ south of the star Lambda (λ) Leonis you'll find the large, bright spiral NGC 2903. This well-known galaxy glows at 9th magnitude and measures 12.6' by 6.6'. NGC 2903 is easily visible in small telescopes and shows spiral structure in large telescopes. A couple of arcseconds northeast of the galaxy's nucleus is the gas cloud NGC 2905. High magnification and averted vision provide the best views of this elusive spot of nebulosity. On really dark nights, NGC 2905 can be seen with direct vision in moderate-size backyard telescopes.

Another well-known galaxy is the large spiral NGC 4559 in Coma Berenices. Part of the Coma cluster of galaxies, NGC 4559 lies about 2° southeast of Gamma (γ) Comae Berenices. Measuring 10.5' by 4.9' and glowing at 10th magnitude, this spiral holds five numbered HII regions. Out of the five I found only three, and one was extremely difficult to see. IC 3564 lies on the southeastern edge of the galaxy. This faint oval haze seems to fade in and out with the seeing and requires averted vision to see well.

West of IC 3564, on the southwestern edge of the galaxy, you'll find IC 3554. This small oval haze requires averted vision to glimpse. The last of NGC 4559's visible HII regions is IC 3555. This extremely faint haze resides about 2' northwest of the galaxy's center. I did not see the remaining two HII regions, IC 3563 and IC 3551.

Moving across the border into Canes Venatici brings the next tar-

get into view. NGC 4395 is a face-on spiral that measures 12.9' by 11.0' and glows at magnitude 10.2. The galaxy has a low surface brightness and lies in an area of sky without any bright stars. What you'll see once you've found NGC 4395 depends on your scope, but for the most part it's a large oval haze with a bright nucleus.

NGC 4400 is the brightest of the two HII regions in NGC 4395 and can be found slightly north and a little east of the galaxy's center. This faint oval smudge is very noticeable and can be seen with direct vision. NGC 4401, on the other hand, is not so noticeable. Lying a few arcminutes south and a little west of the galaxy's center, this faint oval haze requires averted vision for the best view.

Ursa Major holds the last galaxy. NGC 3184 lies in the southern part of the constellation about 1° west of the 3rd-magnitude star Mu (μ) Ursae Majoris. This large, faint galaxy measures 7.8' by 7.2' and glows at magnitude 9.8. It has a bright center surrounded by two prominent spiral arms. Averted vision reveals a number of knots in the arms. The

The big, loose face-on spiral NGC 4395 in Canes Venatici, visible in any scope, contains two bright HII regions.



Chris Schur



Jack Newton

The bright spiral NGC 2903 in Leo contains a single relatively bright gas cloud, visible easily as a spot of light a short distance northeast of the galaxy's center.

galaxy has only two cataloged HII regions, both of which are visible.

NGC 3180 lies just west of the galaxy's nucleus. This faint oval knot can be glimpsed with direct vision but requires averted vision for the best view. NGC 3181 lies a few arcminutes south of the nucleus. It too requires averted vision and a dark night.

By no means has this tour provided an inclusive list of extragalactic HII regions visible in backyard scopes. Remember that with any type of backyard observing, whether it be deep-sky or planetary, dark adaption and a dark observing site will increase the chances of your finding what you're looking for.

And of course the only way to see the things that you read or hear about is to get out under the stars and observe. So wait for a black, moonless night, pack up the telescope, get your best galaxies in mind, and head for your favorite observing site. □

David Higgins is a U. S. Army officer living in Oklahoma City, Oklahoma. By night he explores HII regions.

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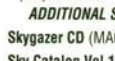


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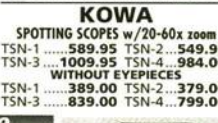
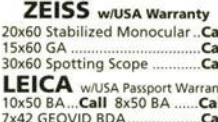
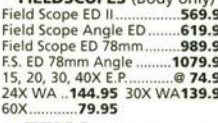
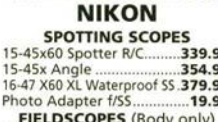
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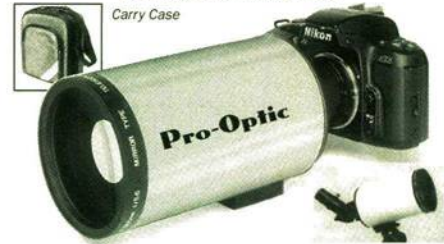
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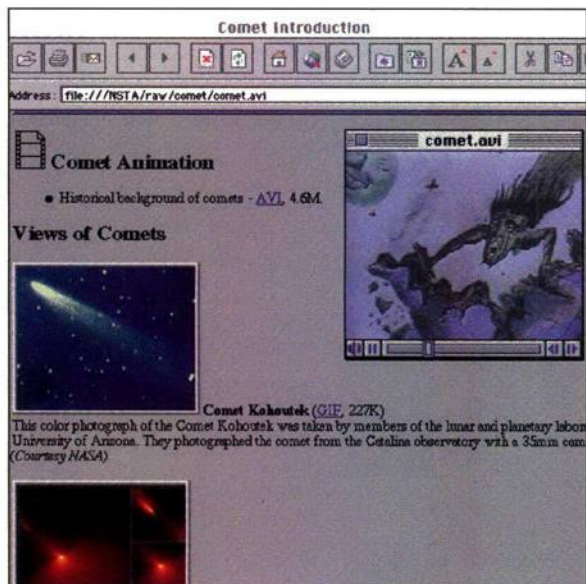
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Views incorporates images, animations, and text to detail the sun, planets, moons, asteroids, and comets. The comet tutorial provides comprehensive information about comets, including the collision of Comet Shoemaker-Levy 9 with Jupiter. This material was created by NASA's Jet Propulsion Laboratory. Additionally, the CD-ROM has a special resources section for educators that includes science activities, National Science Teachers Association journal articles, and more. It also includes Adobe Acrobat Reader and Microsoft Video for Windows (Windows 3.1).

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April is Comet Month in AstroBytes



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IAU (International Astronomical Union) Minor Planet Center — <http://cfa-www.harvard.edu/cfa/ps/mpc.html>

The International Comet Quarterly —
<http://cfa-www.harvard.edu/cfa/ps/icq.html>

Gary Kronk's Comet Page — <http://medicine.wustl.edu/~kronkg/comet.html>

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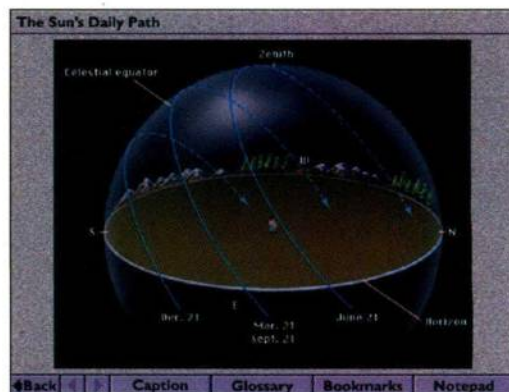
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Product information is as provided by the developer. Software developers may send new programs and upgrades to AstroBytes, ASTRONOMY, P.O. Box 1612, Waukesha, WI 53187-1612 or e-mail bytes@astronomy.com. Check out ASTRONOMY's home page at <http://www.kalmbach.com/astro/astronomy.html>

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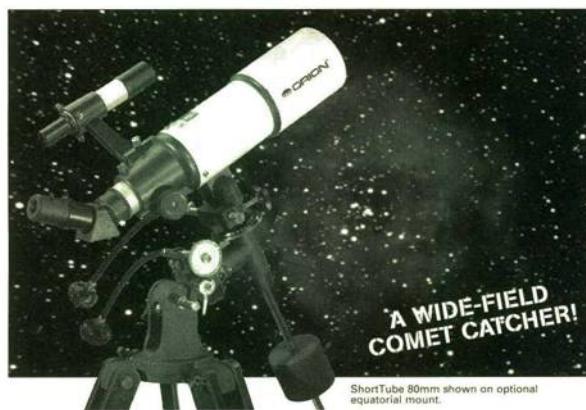
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42mm	#8680	\$127 (3.67)

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The highest contrast, light transmission, and image fidelity obtainable. Superior 5- or 7-element design with Ultra™ Multi-Coatings on every surface and blackened lens edges. Wide 52° apparent field. Removable winged rubber eyeguard blocks stray light and helps position your eye. Threaded for filters. 1.25" barrels.

3.8mm	#8576	\$89 (3.45)
5mm	#8574	\$89 (3.45)
7.5mm	#8572, 10mm	#8570,
15mm	#8568, 20mm	#8566,
		\$79 each (3.45)
25mm	#8564	\$89 (3.45)
30mm	#8562	\$119 (3.45)
35mm	#8560	\$139 (3.45)

FILTERS

ORION

Moon Filters

Cuts glare to reveal more detail.

.965"	#5664	\$15.95 (2.43)
1.25"	#5662	\$15.95 (2.43)

SkyGlow™ Broadband Light Pollution Filters

Rated the #1 broadband filter by Sky & Telescope. "I found the Orion SkyGlow to be the most useful."

For slightly to moderately light-polluted areas.

.965" SkyGlow Fits .965" eyepieces.	#5661	\$44.95 (2.98)
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1.25" SkyGlow Fits 1.25" eyepieces.	#5660	\$69.95 (3.45)
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2" SkyGlow Fits 2" eyepieces.	#5659	\$109 (3.45)
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SC SkyGlow
Fits rear cell of Meade and Celestron Schmidt-Cassegrain scopes.

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UltraBlock™ Narrowband Filters

"The UltraBlock gave superior results."
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For severely light-polluted skies and enhancement of faint nebulas.



.965" UltraBlock Fits .965" eyepieces.	#5655	\$79.95 (2.98)
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We also carry solar filters. See our catalog.

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Ideal for contrast-enhancing planetary and lunar observations and photography with any telescope.



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types of telescopes. The fully-coated optics are mounted in black-anodized aluminum housings with chrome-plated brass barrels for durability and precision fit. Rubber eyeguards. Stock up today!

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12.5mm #8543, 17mm #8544,		
20mm #8545, 26mm #8547		
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32mm, 40mm not available in .965"		

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10mm #8152, 6mm #8153		
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.965" Explorer II		
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10mm #8132, 6mm #8133		
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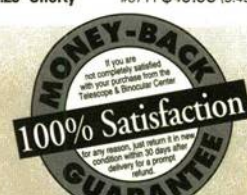
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Slightly higher 9x magnification, 5.0° field of view. Weighs 36 oz.

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25x150 Binoculars

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Heavy-Duty Mount

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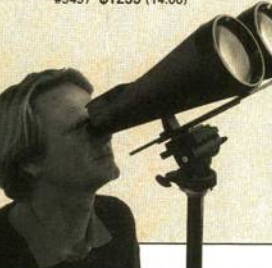


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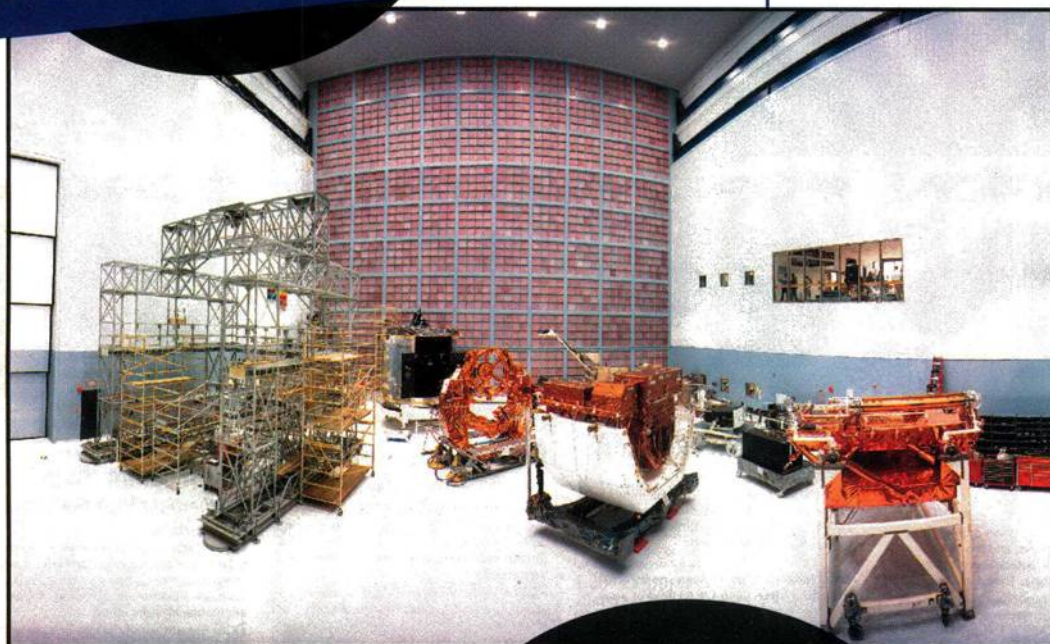
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The 1997 **ASTRONOMY** Sweepstakes
P.O. Box 378
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Cards must be postmarked by May 31, 1997.

Official Sweepstakes Rules:

- 1. No Purchase Necessary.** Official entry forms are bound into the February, March, and April 1997 issues of **ASTRONOMY**. The 1997 **ASTRONOMY** Sweepstakes is open to U.S. residents, 18 years of age or older. Employees (and their dependents and immediate household members) of Kalmbach Publishing Co., their advertising and promotional agencies, and sponsoring companies are not eligible to participate.
- 2. Sweepstakes Entry.** To enter, complete and mail the official postage-paid entry form or a postcard including name, address, city, state, zip and phone to: The 1997 **ASTRONOMY** Sweepstakes, P.O. Box 378, Waukesha, WI 53187-0378. One entry per person. The official ending date for The **ASTRONOMY** Sweepstakes will be May 31, 1997, and all entries must be postmarked no later than that date.
- 3. Prizes and Odds of Winning.** One drawing will be held on or about June 15, 1997 for the following awards: One Grand Prize consisting of three days in Washington, DC, for two people. The trip package includes round trip coach airfare from any city in the continental U.S. (Saturday night stay required), two nights first class hotel accommodations (double occupancy), VIP tour of the NASA Goddard Space Flight Center, standard rental car for three days and \$300.00 cash for meals (retail value \$2,241.00). Winners must travel between July 15, 1997 and November 30, 1997 and travel arrangements must be made at least 30 days prior to departure date. One First Prize consisting of a \$1,000.00 Gift Certificate for a telescope from a retailer selected by the winner. Ten Second Prizes consisting of \$100.00 worth of Kalmbach books/calendars/videos selected by the winners. Twenty Third Prizes consisting of a one-year subscription to **ASTRONOMY** Magazine (retail value \$34.95). Any applicable federal, state, and/or local taxes are the responsibility of the winner. Odds of winning depend on the number of entries received. Total circulation for **ASTRONOMY** is 166,136. Sweepstakes void where prohibited. Florida residents are eligible for prizes.
- 4. Validation.** Winners in The 1997 **ASTRONOMY** Sweepstakes will be selected in a random drawing conducted by an independent judging organization whose decisions are final. By entering the sweepstakes, participants agree to be bound by these official rules and all decisions of the judging organization. Sweepstakes entries void if not legible or completed in full, if not obtained legitimately, or forged, photocopied, mechanically reproduced, late, or tampered with. The potential winners may be asked to sign and return an Affidavit of Eligibility and liability/publicity release within seven (7) days of notification. In the event of non-compliance, alternate winners will be randomly drawn. No responsibility is assumed for lost, stolen, misdirected or late mail. All sweepstakes entries become the property of the sponsor and will not be returned.
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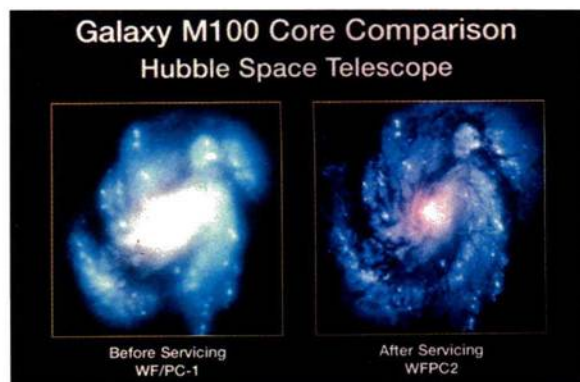
wich, CT 06839; (800) 258-8196; (203) 869-0420; fax, (203) 869-4436; e-mail: triton@tritoncorp.com. The Nighthawk Microlight: \$19.95, plus \$4.95 shipping and handling.



Hubble Slide Set

Hubble in Orbit is a slide set produced by Ireland's Armagh Planetarium and sold in the United States by the Hansen Planetarium. Thirty 35mm slides present some of the best images ever taken with the Hubble Space Telescope, including views of Jupiter's bruised surface after comet Shoemaker-Levy 9's impacts and mergers between quasars and companion galaxies. Information sheets in the vinyl slide-storage folder give a brief biography of Edwin Hubble, the telescope's namesake, and explain how HST and its instruments work. Paragraph-length narratives for each slide tell you what the telescope has revealed to astronomers about objects portrayed in the set.

Hansen Planetarium Publications, 1845 South 300 West, #A, Salt Lake City, UT 84115-1804; (801) 483-5400; fax, (801) 483-5484. *Hubble in Orbit*, Item #1585-7: \$33.75, plus shipping and handling.



Astronomical Mobiles

Send your office, sun deck, or observatory on a whimsical flight of fancy with the *Galaxy* series of metal astronomical mobiles and ornaments. The *Galaxy I* mobile (pictured) spans an area 36 inches wide by 22 inches deep. It features the sun, Saturn, six stars, two comets, and a stylized crescent moon. The smaller *Galaxy II* mobile measures 20 inches deep by 18 inches wide, and has two star, moon, comet, and Saturn figures. Figures are stamped from weatherproofed, anodized aluminum. The mobiles come fully assembled, balanced, and ready to hang. Figures are also available separately as ornaments.

Skyflight Inc., P. O. Box 974, Woodinville, WA 98072; (206) 485-0730; toll-free, (800) 766-8005; fax, (206) 487-6258. *Galaxy I*: \$69.95; *Galaxy II*: \$29.95; Star (4¾" diameter), Saturn (6"), and Comet (7¼") Ornaments: \$3.95; Crescent Moon Ornament (6"): \$5.50; Sun Ornament (7¾"): \$6.50; add \$4 extra for UPS 2nd Day Air.



Birthday Star Catalog

This catalog generated by the Sunstar Observatory lets you find a star that marks a special anniversary. The Birthday Star Catalog lists stars from 4 to 115 light-years away. To look up information on a particular star whose light started its journey to Earth a given number of years ago, scan down the star table to find what star's distance matches your age. An entry tells when to look for the star, the star's name, what constellation it's in, its brightness and color, and the star's celestial coordinates so you can plot its position on a star atlas. The 11-page, spiral-bound catalog includes a section that explains the nature of stars. Birthday, wedding, and memorial star certificates and locator maps are available for an extra charge.

Sunstar Observatory, P. O. Box 59355, San Jose, CA 95159; (408) 236-2952. The Birthday Star Catalog: \$15; Birthday, Wedding, or Memorial Star Certificate and Star Chart: \$10; Engraved plaque certificate: \$45.

New Products presents announcements issued by manufacturers. ASTRONOMY assumes no responsibility for the product information supplied. Prices are retail. Suppliers should send announcements and color photographs to the attention of John Shibley, P.O. Box 1612, Waukesha, WI 53187, or newprod@astronomy.com

Telescope Binocular Viewer

German optics importer Markus Ludes offers the BW Optik Bino binocular viewer to North Americans. The viewer slips into any 1¼-inch focuser to accept 1¼-inch eyepieces. Twist-lock sleeves on each barrel lock the ocular into place. Adjust intraocular distance anywhere between 2¼ inches and 3 inches as you would a set of binoculars. BW Optik Bino's aluminum housing holds multicoated prisms made from BK7 glass that convey a 120mm (4.8-inch) light path guaranteed to ¼-wave. Each unit is laser collimated before shipment to the customer.

APM-Markus Ludes, Kapellenstrasse 6, D-66505 Reifenberg, Germany; phone, 011-49-6375-6345; fax, 011-49-6375-6397. The BW Optik Bino Binocular Viewer: \$795.



Premium-Glass Binoculars

Celestron offers two binoculars built with an extra-low dispersion (ED) glass that virtually eliminates chromatic aberration (color errors) and boosts image contrast and clarity. The *ED Series* binoculars also feature BAK-4 prisms and coatings on all surfaces. The 6.5x44 pair sports a 20mm eye relief and a 7.3° field of view. The 9.5x44 has a 16mm eye relief with a 6° field of view. Both pairs weigh 26 ounces and focus down to 13 feet.

Celestron International, 2835 Columbia Street, Torrance, CA 90503; (310) 328-9560; (310) 212-5835. Celestron ED Series Binoculars, 6.5x44 (Model # 71150) and 9.5x44 (Model # 71151): \$750, suggested list price.

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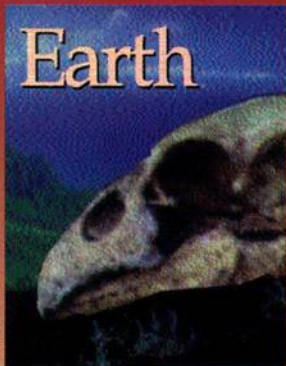
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In the APRIL issue

Earth

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LIFE ON THE BRINK

Scientists see plant and animal species dying off left and right. Humans are often fingered as the cause. But how do we know this die-off rate is unusual and not simply something our planet goes through on a regular basis?

BRIDGE TO THE PAST

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ASTRO BOOKS

Mining the Sky: Untold Riches from the Asteroids, Comets, and Planets

John S. Lewis, 274 pages, Addison-Wesley Publishing Company, Reading, Mass., 1996; ISBN-0-201-47959-1, hardcover, \$26.

Events caught up rather quickly with John Lewis' book *Mining the Sky*. In August, NASA announced possible martian microbes. In September, *Mining the Sky* hit the bookstores. In December, researchers announced possible lunar ice. Suddenly people have places to go beyond low-Earth orbit, but they aren't Lewis' places.

Lewis, co-director of the NASA/University of Arizona Space Engineering Research Center, aims his book at space buffs. It might have been hailed a spaceflight classic today had he written it a few decades ago. He discusses Mars and the moon, but he's really interested in grand-scale asteroid exploitation, with prospectors in spaceships combing the asteroid belt. It's a vision right out of the 1970s, when NASA and space advocacy groups promoted huge spinning habitats and solar powered satellites in space. Their more zealous advocates claimed that space settlements would rain down prodigious wealth from on high. In fact, Lewis' ideas go back further — *Mining the Sky* is essentially just an update of Dan-dridge Cole and Donald Cox's 1964 book *Islands in the Sky*.

But Lewis' chief mission is unrestrained human population growth. As he explains, "the resources of the [asteroid] belt would suffice to sustain a million times as many people as on Earth . . . the best use of the wealth of the asteroid belt is not to generate insane levels of personal wealth . . . the best use is to expand our supply of the most precious resource of all — human beings."

As a space historian, I've been thinking about space settlement since the 1970s. I find the human story of creating new frontier societies breath-

taking. For this reason, Lewis' vision disturbs me profoundly. He writes of acquiring the wealth of the solar system so our progeny can make choices about their future, but the unbridled consumption and expansion he advocates would end the human story.

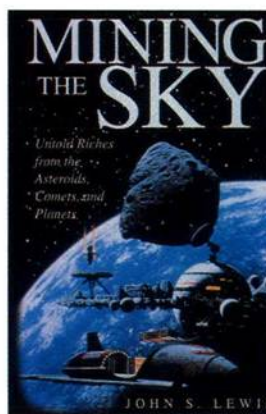
Back in 1973, Isaac

Asimov sounded a cautionary note in his non-fiction book *Our World in Space*. "If anyone thinks that the important reason for exploring space is to find outlets for our expanding population, let him think again . . . within five thousand years, at our present rate of increase, the total mass of flesh-and-blood will equal the mass of the known universe."

Lewis' vision of human prospectors among the asteroids is as much a 19th-century anachronism as his call for unrestrained space conquest. Cheap little robots will soon be able to do everything he advocates with nary a human in sight. Lewis doesn't mention how near-Earth asteroids are becoming so easy to reach that university science departments could soon send their own microprobes. Perhaps he only touches on the role of robots because it would undermine his vision of people plying the asteroids. The balance between robots and humans in space is shifting under the impact of new technology, leaving to humans one role only, that of settling other worlds.

In calling for settlement off Earth, I agree with Lewis. We differ in that I believe it undesirable to pack the solar system to its full carrying capacity at the expense of the wonders that make it worth inhabiting. Humans should live on and experience other worlds and build new societies for themselves. They should choose where they wish to live, not be driven by population pressure into enormous artificial space habitats.

Such habitats can't win a popularity contest against Mars and the moon. This was true even before the discovery of maybe-microbes and a



possible lunar ice-pond. Mars has a sky you can stroll under. Humans bounced and hot-rodged on the moon 25 years ago. By contrast, living in a space habitat would be like living in a can-shaped shopping mall. As for asteroids — well, look at a picture of Ida and the word “potato” comes to mind. And who wants to live on a potato?

We have different visions, Mr. Lewis and I. He sees the population of the solar system leveling off at “10,000,000 billion” people within nine centuries. When the solar system is full, writes Lewis, we’ll build a fleet of 4 billion kilometer-long ships and “send 2.5 million people to each Sun-like star in the galaxy” (his italics). I see Mars’ northern hemisphere and the moon’s nearside turned into parks. Lewis sees the resources of the solar system as “nearly infinite” and “virtually inexhaustible,” forgetting that the same was once said of the American West and the oceans. I see a solar system that must support civilization for millions of years, not just long enough to make a fast buck. In short, he wants the “untold riches” of his book’s title. I want a livable, very long-range future.

— David S. F. Portree

Other Books

The Once and Future Moon

Paul D. Spudis, 308 pages, Smithsonian Institution Press, Washington, D.C., 1996; ISBN 1-56098-634-4, hardcover, \$29.95.

This is a non-technical book from a leading planetary scientist. The first part of the book contains a historical overview of lunar studies. The book next covers what we have learned about the moon from spacecraft, including Apollo and Clementine. The final section discusses why humans should return to the moon, and why our neighbor would be a great place to set up an observatory. The book briefly discusses the possibility of ice at the south pole. □

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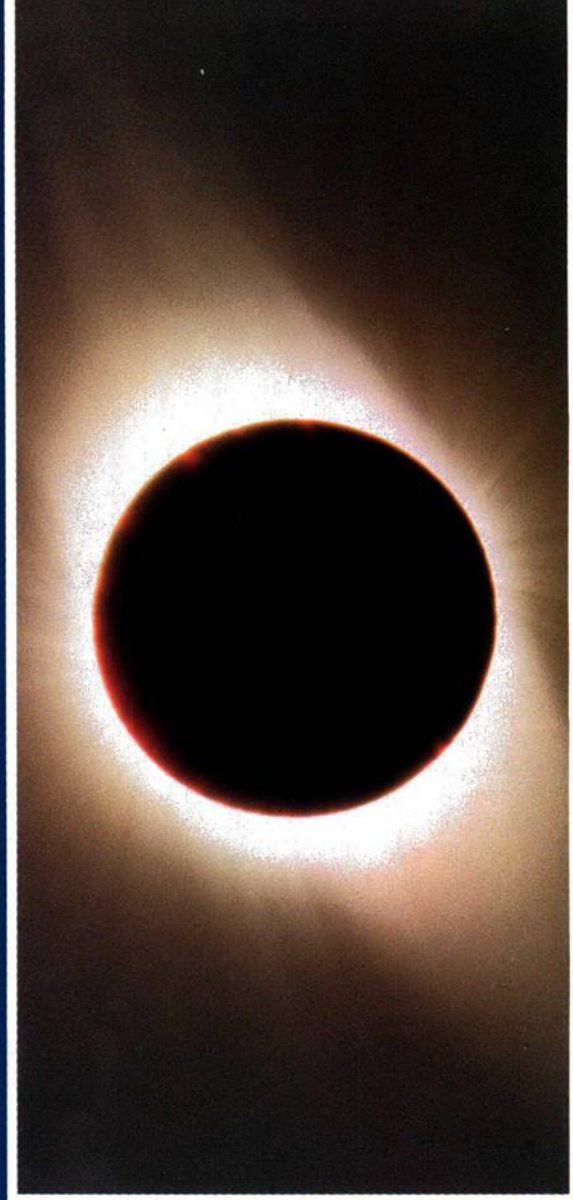
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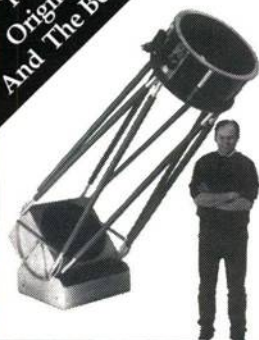
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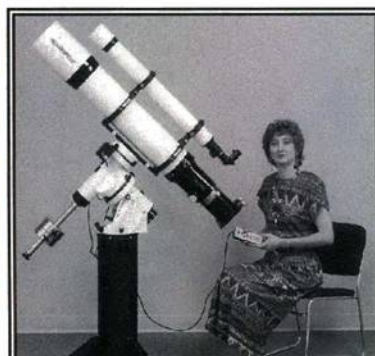


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March 28-April 6

Hale-Bopp Watch, Dower House Touring Park, East Harling, Thetford, Norfolk, England. Sponsored by the Loughton Astronomical Society. Contact Mike Cook, 50 Linley Crescent, Romford, Essex, England RM7 8RD, telephone 01953-717314.

March 29-April 5

Public Star Parties, Otter Creek Park Astronomical Observatory, Otter Creek Park Nature Center, 850 Otter Creek Park Rd., Brandenburg, Kentucky. Contact David Shields, (502) 583-3577, or 942-3641.

April 4-6

The Beach Party - a Star Party, St. George Island State Park, Florida. Sponsored by the Tallahassee Astronomical Society. Contact Joe Haley, (904) 386-1874, or Henry Freedenberg, henryf@freenet.tlh.fl.us.

April 12

Free Comet Party, Ralph Worley Observatory, Hwy. 175, south of Shreveport, Louisiana. Sponsored by the Shreveport-Bossier Astronomical Society. Contact Cran Lucas, (318) 797-1524, clucas@softdisk.com, <http://www.lsus.edu/nonprofit/sbas/>.

April 20

Sixth Annual Northeast Astronomy Forum and Telescope Show, Holiday Inn Conference Center, Suffern, New York. Cosponsored by *ASTRONOMY* magazine and the Rockland Astronomy Club. Contact Don Urban, 73 Haring Street Closter, NJ 07624-1709, (201) 768-6575, urban1@aol.com.

April 25-26

Eleventh Annual NIAGfest Astronomy Convention and GreatCon '97, Camp Crosley, North Webster, Indiana. Sponsored by the Northern Indiana Astronomical Group and the Great Lakes Region Astronomical League. Contact Kurt Eberhardt; 3370 E. Kenway Dr., Warsaw, IN 46580, (219) 269-6289 after 5 p.m. EST.

May 1-4

Peach State Star Gaze, Indian Springs State Park near Jackson, Georgia. Sponsored by the Atlanta Astronomy Club. Contact Ken Poshedly, 3440 Everson Bay Court, Snellville, GA 30278, (770) 979-9842, ken.poshedly@mci2000.com.

May 2-4

Third Annual Delmarva Star Gaze, Tuckahoe State Park, Queen Anne, Maryland. Sponsored by the Delmarva Star Gazers Amateur Astronomy Club. Contact Lyle Jones, 230 N. Bradford Street, Dover, DE 19901, (302) 736-9842.

May 3

Tenth Annual STARCONN Convention, Wesleyan University, Middletown, Connecticut. Sponsored by the Astronomical Society of Greater Hartford. Contact Scott Tracey, 154 Mountain Road, North Granby, CT 06060, (860) 653-0179.

May 4-11

WestTex: West Texas Star Party, Prude Ranch, Fort Davis, Texas. Sponsored by the Prude Ranch. Call (915) 426-3201.

July 1-6

ALCON '97 - Astronomical League Golden Anniversary Meeting and Convention, Copper Mountain Ski Resort, Colorado. Sponsored by the Denver Astronomical Society, Denver University, AAVSO, the Royal Astronomical Society, International Dark Sky Association, and IOTA. Contact Jerry Sherlin, (303) 680-6894, sherlin@aol.com. □

Please submit club announcements four months in advance to *Meetings and Events*, *ASTRONOMY*, P. O. Box 1612, Waukesha, WI 53187-1612, or to tconley@astronomy.com.

RESOURCES PHOTOFACTS

The Strange New Planetary Zoo (page 42)

"Two New Solar Systems," by Robert Naeye, *ASTRONOMY*, April 1996. Discusses the first three extra-solar planets found orbiting solar-type stars and the methods used to discover them.

When Neutron Stars Collide (page 52)

"Gamma Ray Bursters: Near or Far?" by Richard Talcott, *ASTRONOMY*, December 1995. A debate between two prominent scientists on whether gamma-ray bursts originate in our galaxy or far across the universe.

Playing Cosmology's Wild Card (page 56)

Einstein's Greatest Blunder? by Donald Goldsmith (Harvard University Press, 1995). An accessible and up-to-date explanation of the cosmological constant and other unsolved problems in cosmology.

From Russia With Love (page 88)

Star Testing Astronomical Telescopes, by Harold Richard Suiter (Wilmann-Bell, 1994). One of the best resources for testing and evaluating telescope optics under the stars.

p. 62: Comet Hyakutake in Perseus, Myron Wasiuta, 35mm f/2.8 lens, Fuji 800 G film, 60 seconds, 4/17/96; p. 67: Comet Hyakutake, Jeff Peronto, 300mm f/4 lens, Fuji 800 Super film, 9 minutes, 4/16/96; p. 68: The Frosty Leo Nebula, Tim Puckett, 12-inch f/10 Schmidt-Cassegrain telescope, Axiom AX-7 CCD camera, 5-minute exposures through red, blue, and green filters; p. 71: Comet Hale-Bopp, Tim Puckett, 12-inch f/10 Schmidt-Cassegrain telescope, Axiom AX-7 CCD camera, 2-minute exposures through red, blue, and green filters, 11/27/96; p. 72: Comet Hale-Bopp, Tim Puckett, 30-cm f/10 reflector with an Axiom AX-7 CCD camera, 2 minutes, 11/27/96; p. 75: Comet Hale-Bopp, Al Kelly, 32-inch f/4 reflector, tri-color, stacks of 15-second exposures, 10/9/96; p. 76: Comet Hale-Bopp, Robert Suding, 8-inch f/4.5 telescope and a Cookbook 245 camera, 20 seconds, 11/28/96; p. 77: Comet Hale-Bopp and M14, Gordon Garradd, 10-inch f/4.1 Newtonian, hypered Kodak Gold III, 10/29/96.

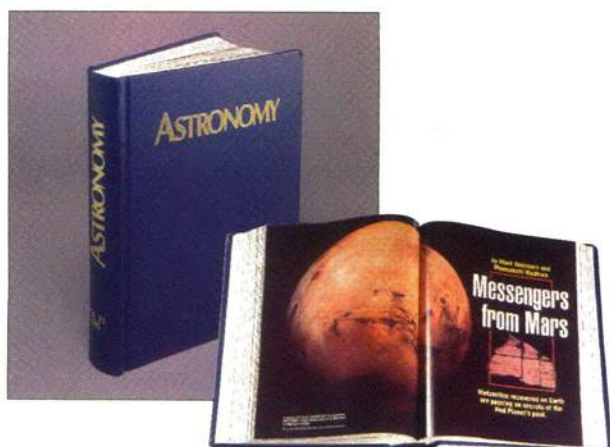
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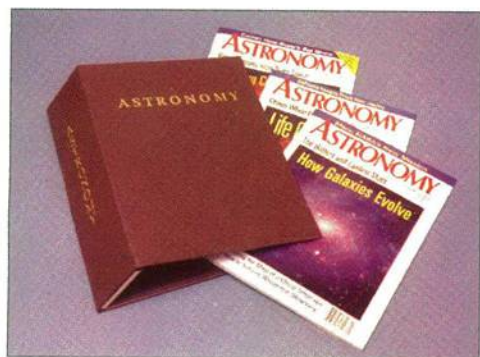
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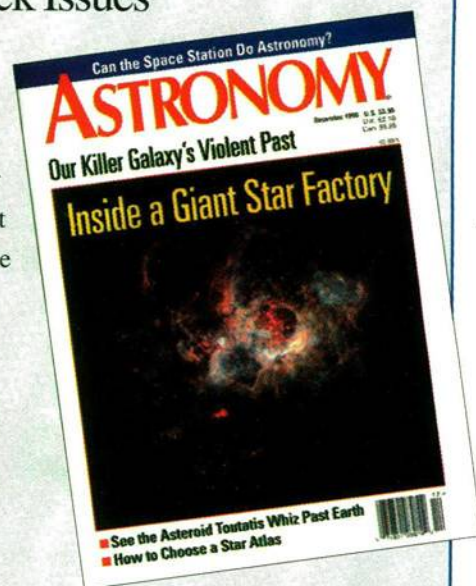


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J. P. Harrington, K. J. Borkowski, and NASA

INSIDE A STAR'S COCOON

When stars like the sun die, they give birth to some of the most beautiful structures in the universe.

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Of Comet Wings and Shooting Stars

Watch out! Once in a while the sky will throw a curve that leaves you hard-pressed for an explanation. California observer David Chandler experienced this first hand last autumn with a faint comet called Tabur. To Chandler's trained eye, the comet seemed to leave a trail of debris several degrees in length along its orbital path. With some difficulty, Chandler realized he could trace the trail through a rich-field telescope or binoculars.

It all began on September 8 during the annual "Nightfall" star party held in Borrego Springs, California. "I observed a glow that extended several fields of view from the comet," he recalls. "As I traced it, my wife followed the telescope's position with a cursor on our laptop computer nearby." Chandler's wife Billie immediately noticed he was tracing the orbital path of comet Tabur.

Over the next two months, the Chandlers and three fellow observers repeatedly spotted the feature, which in late September extended from the comet's predawn position in Orion to the south, all the way to Ursa Major in the northeast.

But repeated attempts by other observers and astrophotographers to catch the band were unsuccessful. Even a search by professional astronomers using instruments that would have picked up a debris field's subtle heat signature turned up nothing. Consequently, the



Leonid Meteor Streaks through Hydra

Frank Zullo

(35mm f/2.8 lens, Fuji Super G 800 film, 7-minute exposure, foreground added by duping onto Kodak 5072 film)



Partial Solar Eclipse over the Swiss Alps, October 12, 1996

Harald Liederer and Bernd Liebscher
(1000mm lens at f/10, Kodak Professional 200 slide film, 1/250-second exposure)

International Astronomical Union's Central Bureau of Astronomical Telegrams did not to issue a telegram of discovery.

"This might be an example of visual observers reinforcing something they feel they are honestly seeing, but in reality isn't there," says CBAT coordinator Dan Green. "The same thing happened to history's greatest Mars observer, Percival Lowell." The famous 19th-century astronomer thought he saw canals crisscrossing the surface of the Red Planet.

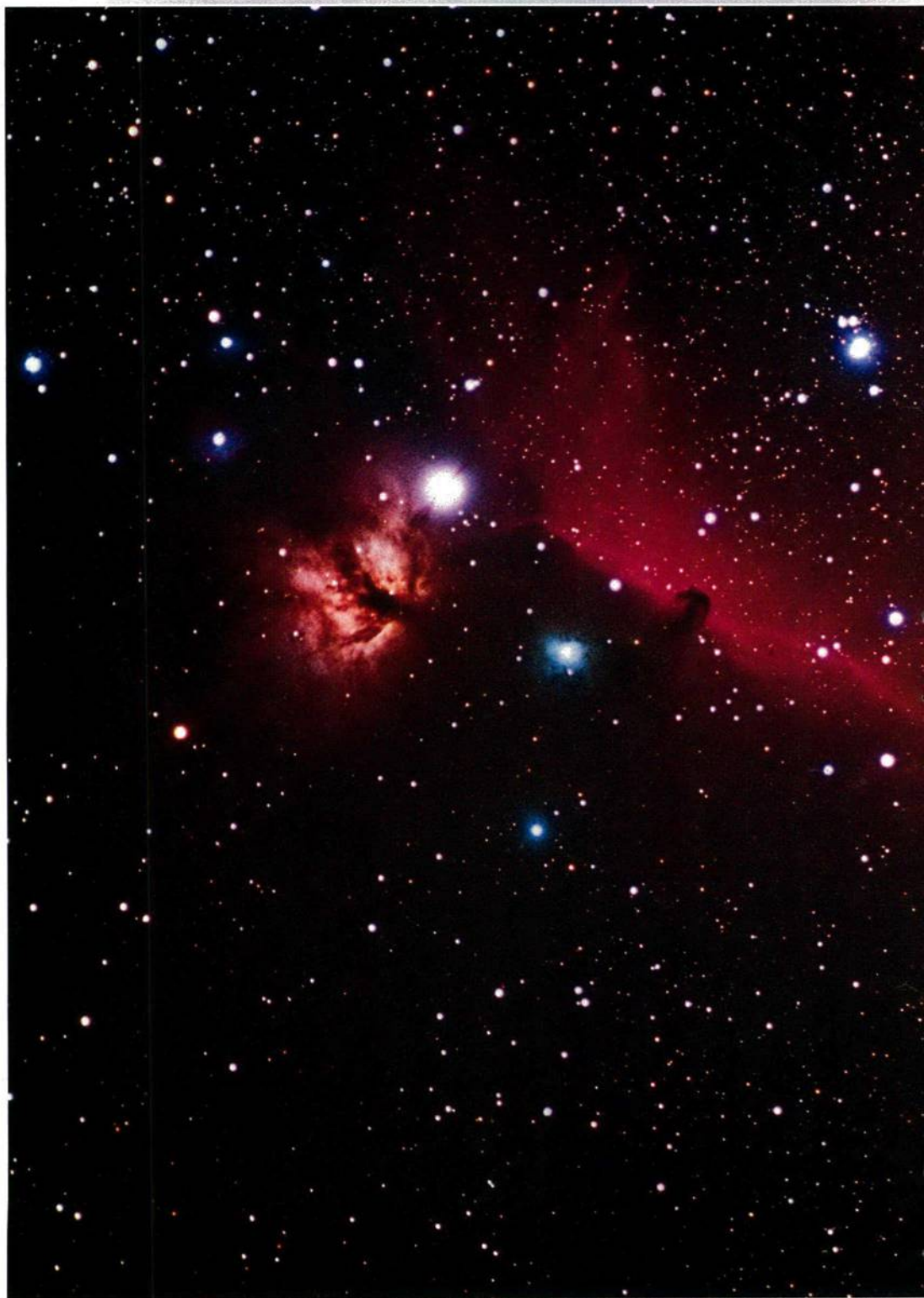
But Chandler and company remain adamant that they saw something. "One observer commented to me that the Zodiacal Band, which may be of similar low contrast, is rarely photographed," he says. Perhaps there are some sights in the cosmos that only human eyes can catch.

Autumn's popular Leonid meteor shower was one sight more than easy to see. George Gliba and other members of the Westminster Astronomical Society trekked to rural West Virginia on the morning of November 17 to watch shooting stars stream from Leo. They witnessed 223 meteors during a four-hour period, 156 of which were bona fide Leonids.

"Many were bright fireballs," Gliba reports. "One -4-magnitude bolide passed just below Sirius (the sky's brightest star at magnitude -1.5) to leave a train that glowed for more than seven minutes."

Holtsville, New York, observer Frank Melillo thinks the '96 Leonids put on the best shower since the Perseids of 1993.

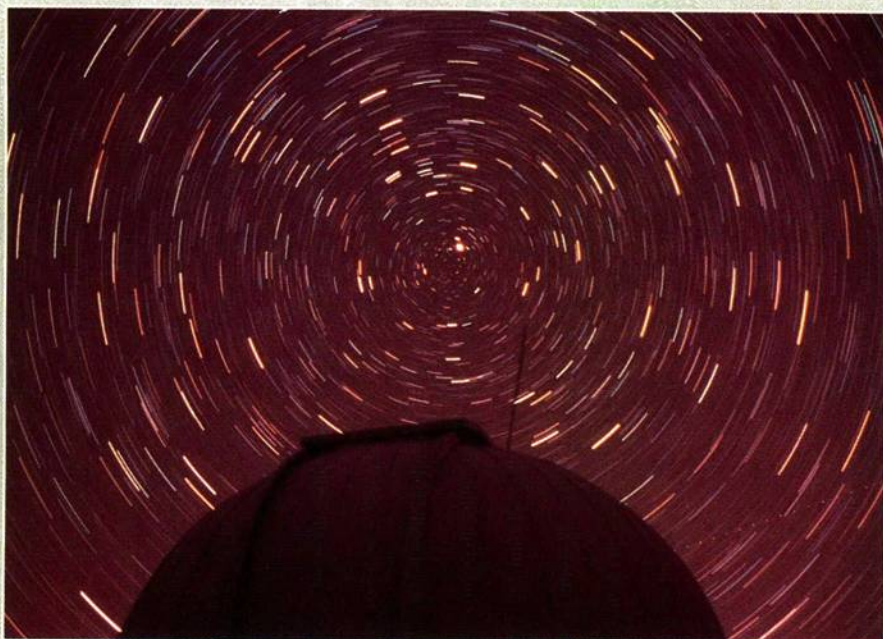
"About 70 percent of them left vapor trails and 55 percent were 0-magnitude or brighter," says Melillo of his observations done between 1:30 a.m.



The Horsehead Nebula in Orion

Vince and Maggie Farnsworth

(4-inch f/5 refractor, Kodak PPF 400 film, composite of four 45-minute exposures)



**Star Trails over
an Observatory in
Baja California**

Alberto Levy
(50mm f/2.8 lens,
Fujichrome Provia
100 film, 30-minute
exposure)



**Moonset with
Jupiter and an
Organ Pipe Cactus**

Frank Zullo
(35mm f/2 lens,
Fujichrome Provia 100
film pushed to ISO 400,
17-second exposure,
foreground illuminated
with a flash)

and 5:40 a.m. Eastern Standard Time. He noted an average hourly rate of 250 meteors near the predicted 3:20 a.m. EST peak, about five times last year's rate.

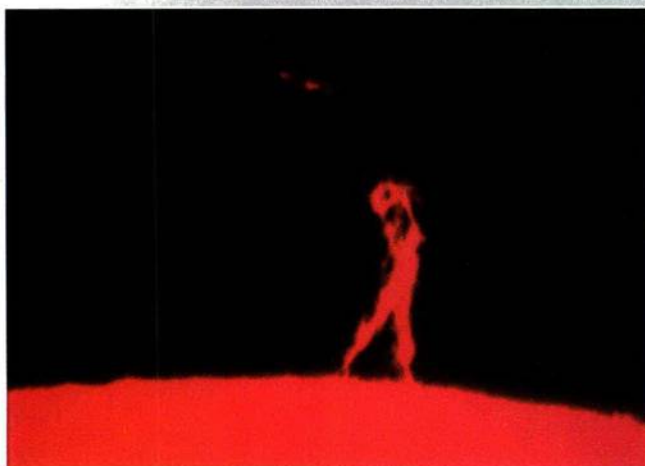
The holiday season's other active, prominent shower, the Geminids, also put on a show over the nights of December 12 and December 13.

California meteor watcher George Zay glimpsed 266 Geminids over an eight-hour period on December 13/14, including a brilliant -8 bolide that passed through his zenith. He noticed a slightly higher level of activity the night before: 380 meteors, but fewer bolides.

Perhaps the most unusual Geminid observations come from Peter Ward of Guildford, England, who was on a 747 flight between Los Angeles and London on the night of December 13/14.

"I had my nose pressed against the window for a couple of hours, and saw about 45 meteors an hour," he recalls. "Visibility varied significantly, thanks to a guy next to me who was more interested in reading his newspaper." □

ASTRONOMY wants to share your observations of the sky with readers. Send reports, sketches, photographs, and disks to John Shibley, Reader Reports Editor, ASTRONOMY, P.O. Box 1612, Waukesha, WI 53187-1612. Please label each photo with photo data, name, address, and social security number. You will be notified if ASTRONOMY adds your photo to its files for future publication. A self-addressed, self-stamped envelope facilitates the return of any photos the magazine can't keep or publish. Send written reports and images via the Internet to: rreports@astronomy.com.



Prominence on the Sun

Gordon Garcia and R. Radhakrishnan
(130mm f/8 refractor working at f/32, ST-5 CCD camera, 1/20-second exposure through a H- α solar filter)



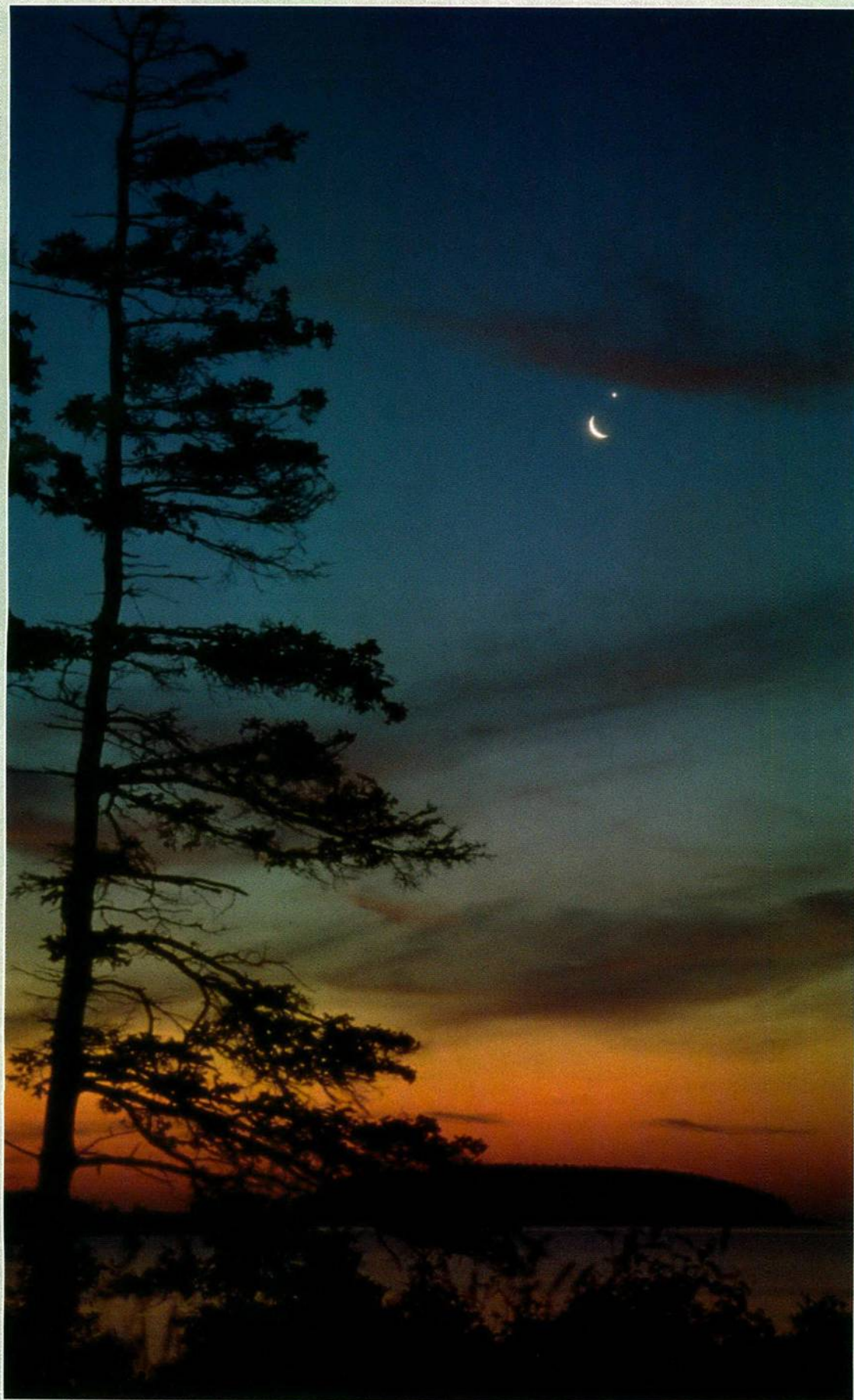
Crater Posidonius Five Days after Full Moon

Cesar Descordes
(9-inch Cassegrain telescope, Tech Pan 2415 film, 1.7-second exposure)

Terminator of a Last Quarter Moon

Grant Leffingwell
(32-inch f/16.4 reflector stopped down to a 9 1/4-inch f/17.2, CB245 Cookbook CCD camera, mosaic of 14, 1/4-second exposures)





**Conjunction between
the Moon and Venus,
July 12, 1996**

Robert P. Clark
(35-105mm zoom lens at
f/8 set to around 80mm,
Kodak Elite 100 film,
1-second exposure)

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M8, the Lagoon Nebula, in Sagittarius

Tony and Daphne Hallas

(6-inch f/7.7 refractor, hypered Fuji SHG 400 film, composite of two 45-minute exposures)

This superb photo of an active star factory captures not only a summer showpiece for backyard telescopes, but its seldom-seen — much less photographed — tendrils of gas that extend far to the east. The Lagoon Nebula and the young stars that make it glow red lie 5,200 light-years away. Below and to the left of M8 is the globular star cluster NGC 6544, some 15,000 light-years distant.

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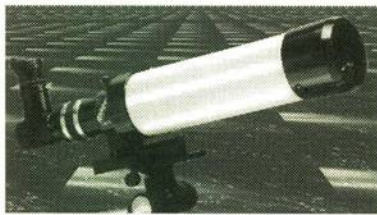
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The "spacewalk" eyepiece! Patented & tested to be the best! Fully multi-coated, eyeguards. 20, 16, 13, 12, 9, 7, 4.8mm

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Introducing the 19mm



The 68° Panoptic family welcomes the arrival of its new 7oz, 1 1/4" 19mm. A "killer" with Bino Vue! 35, 27, 22, 19 & 15mm

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Preferred Plössl in S&T comparison review. Fully multi-coated, patented Nagler design. 55, 40, 32, 25, 20, 15, 11, 8mm

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Paracorr corrects coma and flattens the field of "DobNewts," increases diffraction limited field area by 36 times and slips into a 2" focuser like a Barlow! Essential for f/4 — f/5 scopes. See perfection emerge.

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Bino Vue features in-line viewing for terrestrial and astronomical observing, no focus shift during inter-ocular adjustment, large, multi-coated prisms and Tele Vue quality control. Dramatically transforms any scope!



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Nagler designed for optimum performance. NO aberrations, just magnification! 2x &



3x (1 1/4"), 2x (2") with captive screw & parfocal 1 1/4" eyepiece adapter. Fully multi-coated and threaded for filters.

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SCTowners—Get Rich Quick!

Nogimmicks. Maintain the optical integrity of your scope and increase its



field area by 3 times with our Rich Field Kit. The kit includes adapters, 2" diagonal and 55mm Plössl for maximum true field. Use the 35mm Pan. & 20mm N2 too!

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What a trip!

Rock-solid wood tripod with alt-az head. Sky Tour computer available for finding and identifying 2000 objects selected by author Tom Lorenzin. Great with all Tele Vue scopes. Full object listing included.



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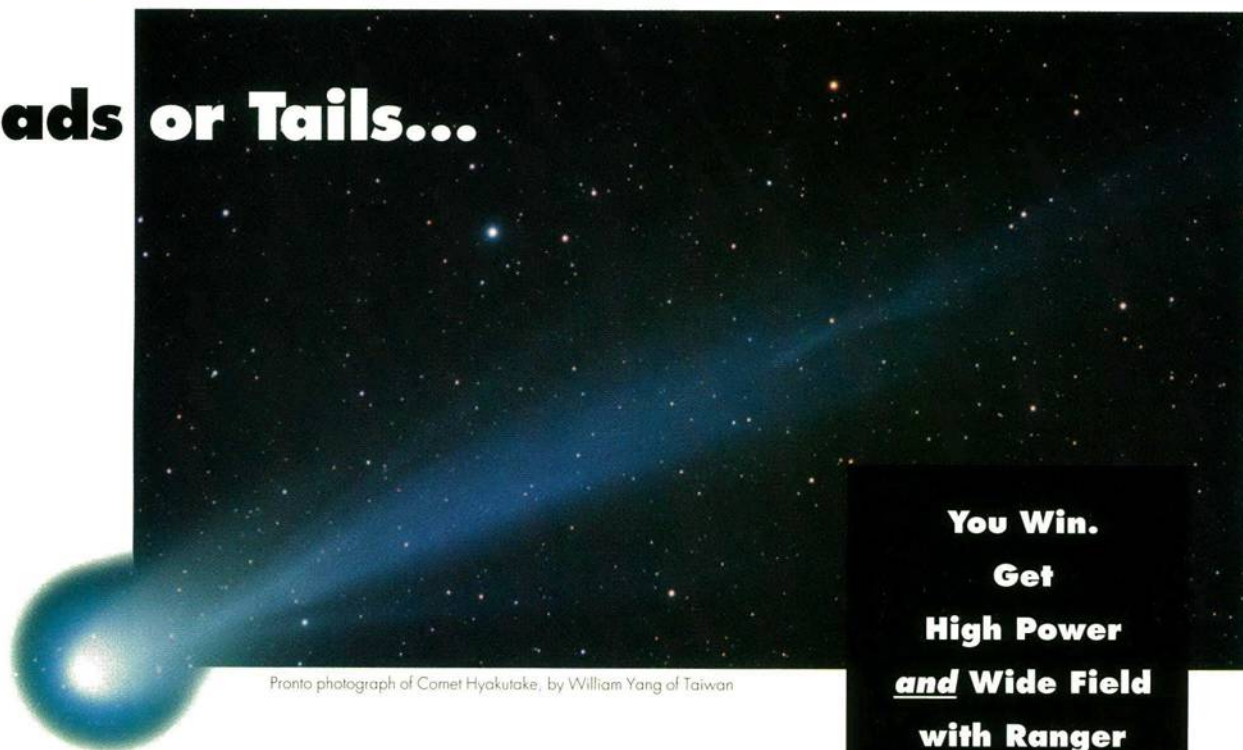


Tele Vue is proud to deliver fellow amateur astronomers a selection of the finest eyepieces, telescopes and accessories. Our enthusiasm for astronomy is carried into our products; adding thoughtful touches such as anti-reflection threads on internal barrel surfaces, captive screws where possible and safety undercuts to name a few. Tele Vue products are designed, manufactured and tested to be fully appreciated in the field. Discover the Tele Vue experience!

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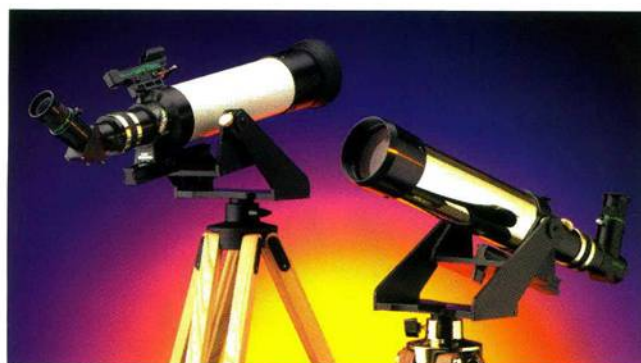
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Heads or Tails...



Pronto photograph of Comet Hyakutake, by William Yang of Taiwan

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Ranger

- I wanted an extremely portable instrument of superb quality. I consider Pronto to be the Questar of refractors. It is of superb manufacture and the views are razor sharp with beautiful contrast. — J.B. AZ
- I really like the RFT/diffraction limited design. And, Pronto was within budget. I'm very pleased! Not only could I see Io's shadow clearly transit Jupiter (at 95x), but I could trace Io itself across the planet's darker limb - even in front of a lighter band of clouds. Thanks again. — B.O. IL
- I'm impressed. Ranger performs like a larger aperture telescope. A star test revealed perfect diffraction patterns. — A.G. TX
- Great optics, great machining. Spectacular low-power views; seems much larger than 70mm; lots of detail on high power Jupiter. — P.R. NY
- I needed a grab and go scope with guts. Ranger is an astounding instrument! My 8" can't keep up with this rascal — N.R. NE
- I need portability; to carry on flights - (airline crew). Pronto is a beautiful scope; my first look at Jupiter and Saturn convinced me I had made the right choice. Thank You. — P.H. Hong Kong



Pronto

	Ranger	Pronto
Objective:	2-element, E.D.	Same
Power Range:	12x - over 200x	9x - over 200x
Visual Field:	3.3°	5.5°
Photo Field:	5.2° 35mm film diag.	Same
Aperture:	70mm	Same
Focal Length:	480mm	Same
Focal Ratio:	f/6.8	Same
Focus Type:	1 1/4" 2 Stage with Helical	2" Rack & Pinion
Dew Shield:	Available	Captive, Sliding
Mounting:	1/4-20 Balance Bar	1/4-20 Mount Ring
Carry Bag:	Available	Custom Padded
Choices:	1 1/4" Mirror Diag., 1 1/4" 45°, or Porro Prisms	2" or 1 1/4" Mirror Diags., 1 1/4" 45°, or Porro Prisms
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Celestron Introduces the PixCel 255™ CCD Camera

Getting the kind of images you want of stars, planets, galaxies and more — beautiful photos like the ones you've seen in books and magazines — used to require years of practice, excellent conditions and lots of patience.

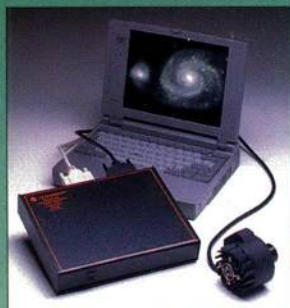
Celestron has teamed up with Santa Barbara Instrument Group (SBIG), the leader in the design and manufacturing of CCD cameras, to bring you the ultimate CCD camera:

At 3 1/4" in diameter, the PixCel 255 is the smallest, most advanced, full featured CCD camera available. It's ideal for 5" to 11" telescopes, affordably bringing the option of tricolor imaging to smaller telescopes.

The PixCel 255's advanced new CCDOPS software is fast and easy to use. New images are captured and displayed very rapidly, with full frame download in under four seconds.

Unlike other CCD cameras, the PixCel 255 offers an optional internal color filter wheel with a simple, one-time installation. Once the filter

Now, with Celestron's new PixCel 255 CCD camera, you'll be taking dazzling astrophotos using electronic CCD imaging in no time. Even if you're a novice, you can be up and running, taking your first image in less than an hour.



PixCel 255 CCD camera shown with laptop computer (not included).

wheel is installed, you have a fully integrated color imaging system, providing state-of-the-art tricolor images.

CCDOPS software automatically takes dark frame images, eliminating the inconvenience of covering and uncovering the end of the telescope manually.

The PixCel 255 camera is fully compatible with Celestron's new Fastar™ f/1.95 telescope; available in early 1997. The

PixCel 255 and Fastar™ telescope together offer the ultimate way to capture the stars in fast and easy unguided tricolor images beyond any you've dreamed possible.

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